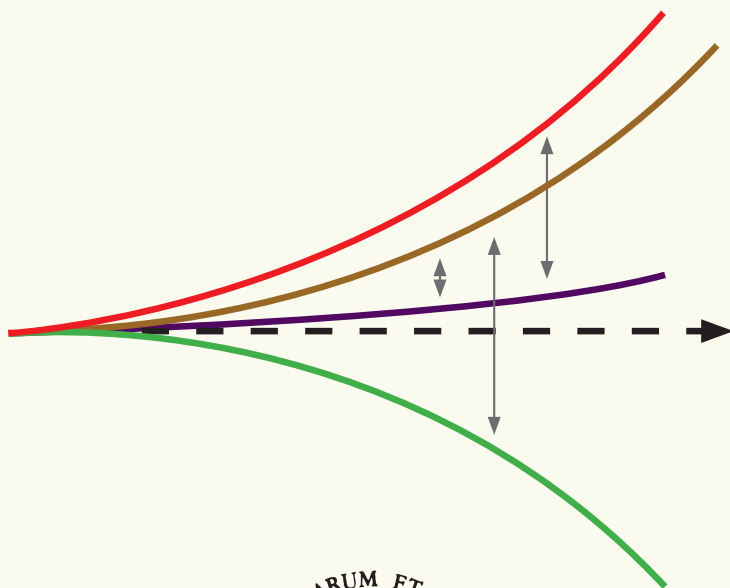


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OF THE 6TH INTERNATIONAL CONFERENCE
ON THE ECONOMICS OF DECOUPLING (ICED)**

**ZBORNIK RADOVA 6. MEĐUNARODNE
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**ECONOMIC GROWTH
and SUSTAINABLE DEVELOPMENT**

EXPLORING THE LINK BETWEEN RESOURCE EFFICIENCY ACTIONS AND PRODUCTION COST REDUCTION – EVIDENCE FROM CROATIAN FIRMS

Ljiljana BOŽIĆ*

The relationship between environmental initiatives and their effects has been extensively explored in literature. One of the often-studied topics is how resource efficiency actions affect production costs. These actions are generally expected to contribute to a decrease in production costs. However, the relationship is not simple, as a production cost decrease may not occur primarily due to the rebound effect (i.e., lost part of the energy conservation) and the costs that come with resource efficiency actions. It is, therefore, worth exploring what determines production cost change.

This paper explores the determinants of production cost change in firms implementing resource efficiency actions, focusing on the Croatian experience. The aim is to understand how investment in resource efficiency, support for its implementation, and problems during implementation affect production cost change in a country that generally scores low on environmental performance compared to other EU countries. Data from Flash Eurobarometer 498 - SMEs, green markets and resource efficiency, provided through the GESIS Archive, are used in the empirical part of the study. The sample includes data for over 500 firms operating in Croatia.

As for the method, the ordered probit with sample selection is employed. It was the most adequate method for handling order outcomes (i.e., production cost change measured as increase, remaining the same, and decrease) with selection bias. Independent variables in the model are the percentage of turnover invested in resource efficiency, internal and external support to resource efficiency implementation, and problems encountered during the process. The model controls for the market, firms' size, and age.

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Descriptive statistics reveal that most firms implement resource efficiency strategies, with over one-half reporting reduced production costs. Results of the ordered probit with selection show that the probability of reducing production costs in Croatian firms that implement resource efficiency actions is determined by optimal investment in resource efficiency, as well as the costs incurred during the implementation of environmental actions.

This study contributes to the existing body of knowledge by providing empirical evidence on the factors determining the benefits of resource efficiency actions in firms operating in a country whose environmental performance lags behind the EU average. These findings are relevant for understanding how firms can benefit from ecological initiatives, more precisely, resource efficiency actions, as they are often implemented due to regulatory pressure. These findings imply that policymakers should design adequate measures to help firms alleviate costs related to resource efficiency action.

However, the study is limited to one country only. Future studies should explore whether these findings hold in countries with similar environmental performance.

Keywords: *resource efficiency actions, production costs, ordered probit with selection, Croatia*

JEL classification: *Q59*

INTRODUCTION

The term “resource efficiency” encompasses the technical efficiency of resource use (i.e. the useful energy or material output per unit of energy or material input), the extent to which economic value is added to a given quantity of resources and the extent to which resource use has negative impacts on the environment (UNEP, 2017). Flash Eurobarometer 498 defined resource efficiency more narrowly as using natural resources in a sustainable and environmentally friendly manner, from supply to waste management.

Resource efficiency actions are recognized in the literature as one of the important drivers of business performance growth. According to Koszarek-Cyra (2016), cost savings are the main motive of firms in implementing environmental actions. Extant empirical findings testify to the benefits of resource and eco-efficiency actions on firm performance (Majid et al., 2020). Among

others, resource efficiency actions contribute to a decrease in production costs (Langs, 2024).

Some resource efficiency actions are aimed at savings (of water, energy, material, etc.). This makes them appealing to firms whose strategic orientation is on cost leadership, especially in times of economic downturn (Delmas and Pekovic, 2015). Still, some are more complex and require change towards renewable energy, recycling of materials, and product design that support sustainable use and hence, include higher investments and expenditures. These expenditures, however, can be outwaited, at least partly by benefits made elsewhere (Ambec and Lanoie, 2008).

Extant research on resource efficiency and production costs in Croatian firms shows a favorable relationship. More precisely, firms that engage in resource efficiency on a large scale are likely to reduce their production costs (Pekanov Starčević, Mijoč and Zrnić, 2017). This research goes one step further and explores factors determining production cost decrease in such circumstances. The research aims to understand how investment in resource efficiency, support for its implementation, and problems during implementation affect production cost change in Croatian firms.

This study is expected to contribute to the literature by providing empirical evidence on the determinants of production cost change in firms implementing resource efficiency actions in a country that generally scores low on environmental performance compared to other EU countries. The Eco-Innovation Scoreboard shows that Croatia is one of the EU countries with the lowest environmental performance. Among other indicators, Croatia lags in resource efficiency outcomes (more details are provided in a subsequent chapter).

Extant findings indicate that obstacles such as deficient environmental and industrial policies and the lack of awareness about potential productivity increases stimulated by those activities prevent firms in transition economies from engaging in environmental protection (Diaz-Garcia, Gonzalez-Moreno and Saez-Martinez, 2015). Central and Eastern European national policies still diverge from the common EU policy framework on resource efficiency (Domenech and Bahn-Walkowiak, 2019). That raised the issue of policy quality in these countries, as their progress in environmental performance is relatively slow. Issues such as mismanagement of public resources and insufficient funding are some of the main reasons for the struggle with environmental protection in transition countries (Sezer, Kocasoy, and Aruoba, 2003). It is, therefore, worth analyzing the factors that enable a change in production costs for firms in Croatia that decide to implement resource efficiency actions.

The remainder of the paper is organized as follows: Section 2 reviews relevant literature, and Section 3 explains the methodology. Section 4 presents and discusses research results. Finally, section 5 provides conclusions, study limitations, and future research directions.

BACKGROUND LITERATURE

A transition towards green economy puts environmental innovation in the focus of academics, policymakers, managers, and other stakeholders. Resource efficiency actions are one of the eco-innovation types, namely eco-innovation in processes. The Maastricht Manual on Measuring Eco-Innovation for a Green Economy (Kemp et al., 2019) defines eco-innovation in processes as the new or improved processes that increase resource efficiency by reducing the use of environmental resources per unit of goods or service production. This implies new processes that use less energy, material, water, or other physical inputs per unit of output or operation, as well as those that reduce the amount of waste by preventing its production or re-using waste in the production process.

Implementing environmental action and innovations generally contributes to environmental protection and improves business performance (Beise and Rennings, 2005). Galant and Cvek (2021) show that environmental performance investments help firms increase their profit or lower their loss, i.e., positively affect their financial performance. Firms that report resource efficiency practices attain higher cost savings than those with no such activities (Rennings and Rammer, 2009). Systematic literature review shows that most empirical studies show positive effects of environmental innovation on cost reduction (Hermundsdottir and Aspelund, 2021).

The opportunity to reduce production costs through environmental actions can improve financial performance, which has been identified as one of the most common motives for implementing environmental practices (Baines et al., 2012). Reduced costs also enable firms implementing environmental practices to outperform their competitors (de Ron, 1998). While the possibility of production costs decreasing due to resource efficiency actions sounds appealing, there is no guarantee that it will occur. The rebound effect is one of the main reasons why the production costs may not decrease. The rebound effect refers to the lost part of energy conservation due to extra demand generated by lower costs (Berkhout, Muskens and Velthuisen, 2000). Cost savings that come with environmentally friendly solutions can result in environmental pressure, i.e., they can have a rebound effect (Vivanco et al., 2016). Besides,

resource-efficient technologies may cause unforeseen costs that, in the end, hamper the decrease of production costs (Schleich, 2009).

As for the Croatian firms, they implement sustainability and environmental action to meet EU requirements rather than to achieve positive environmental impacts (Zrnic, 2022). Literature on environmental innovations recognized regulations as one of the most important drivers of change toward eco-friendly practices, along with cost savings (Horbach, Rammer and Renning, 2012). The existing and expected regulations significantly influence the inclination to implement environmental practices (Doran and Ryan, 2012).

The eco-innovation performance of EU countries, including Croatia, is assessed annually and presented on the Eco-Innovation Scoreboard. Croatia is currently ranked among the eco-innovation catching-up countries, the group with the lowest environmental performance. Croatian performance has significantly improved over the last ten years, notably in 2023. The latest edition of the Eco-Innovation Scoreboard shows that Croatia was among the top performers in the group of catching-up countries, but still ranks nearly 31 points below the EU in 2024 (European Commission, 2024).

The improvement is driven by increases in eco-innovation-related academic publications, the number of ISO 14001 certificates, and greenhouse gas productivity. These three indicators are above EU-average growth. It is worth noting that Croatia underperforms in socio-economic outcomes (exports of environmental goods and service sector, employment in environmental protection and resource management activities, and value added in environmental protection and resource management activities) and resource efficiency outcomes (material productivity, water productivity, and energy productivity). Among others, the main challenges of Croatian eco-innovation performance are low competitiveness and lack of growth opportunities that prevent Croatian firms from investing more in green products (Vrabec and Hranilović, 2022).

Environmental challenges vary by sector and consequently pose different opportunities for firms in these sectors. Some sectors are more polluting than others (e.g., manufacturing vs. services, but differences also exist within the sectors). Interestingly, there is a lack of research on environmental practices in high-polluting sectors such as transportation and logistics, chemicals and pharmaceuticals, oil and gas, and mining (Balasubramanian et al., 2021). Extant findings show that high-polluting sectors are more prone to environmental certification (Heras-Saizarbitoria, Arana and Boiral, 2015), but also that they are more likely to invest in environment protection if they have caused polluting accidents (Sarmiento and Duarte, 2004). It is, therefore, important to consider if there are some differences between sectors regarding production cost change.

Extant findings show that firms' willingness to introduce eco-friendly processes is determined by firm size, and they are most likely to be conducted by medium-sized firms (Hoogendoorn, Guerra, and Zwan, 2015). Furthermore, larger SMEs are more likely to engage in environmental practices, especially those operating in tangible sectors (Uhlaner et al., 2012). These findings call for controlling for the sector and firm size in order to understand production cost change in firms that implement resource efficiency actions. Additional justification for considering the firm size resides in the structure of firms in Croatia. Data from the Croatian Bureau of Statistics shows that the Croatian economy is dominated by firms that employ less than 249 employees (Croatian Bureau for Statistics, 2024). This should be considered when studying and understanding resource efficiency practices in Croatian firms.

DATA AND METHOD

The empirical part of the paper relies on microdata for 553 firms in Croatia obtained from Flash Eurobarometer 498 - SMEs, green markets and resource efficiency, provided through the GESIS Archive. Flash Eurobarometer 498 is the fifth wave of a survey on resource efficiency and green markets. Eurobarometer surveys are often used in research focusing on green markets and resource efficiency (for example, Hoogendoorn et al., 2015; Koszarek-Cyra, 2016, González-Moreno et al., 2016; Aguado and Holl, 2018; Majid et al. 2020; Langs, 2024), including the research on Croatian firms (Pekanov Starčević, Mijoč and Zrnić, 2017; Zrnić, 2022).

The dataset includes responses from manufacturing, industry, retail, and service firms. The sample comprises 20.43 percent of manufacturing firms (NACE section C). A total of 31.65 percent of firms in the sample operate in the retail sector (NACE section G). Furthermore, 19.89 percent of firms are from the industry (NACE sections B/D/E/F), while the remainder (28.03) are service firms (NACE sections H/I/J/K/L/M).

This survey focuses on SMEs, and most firms in the sample are small and medium-sized enterprises. However, 7.59 percent of them employ more than 250 employees and, in that respect, are categorized as large firms. As this research is not focused on SMEs, large firms are not excluded from the analysis.

The dependent variable in the model is production cost change measured on the ordinal scale (production costs have increased, remained the same, or decreased over the past two years). The type of dependent variable calls for an ordered outcome model. Furthermore, the Flash Eurobarometer 498 provides

data on the production cost change for firms that report resource efficiency actions. Data for production costs of firms without resource efficiency engagement in the past two years have not been observed. It is, therefore, hypothesized that the unobservables that affect the cost of production correlate with the unobservables that impact the probability of resource efficiency actions. In other words, firms decide to implement resource efficiency actions relying on their expected impact on production costs. This assumption calls for an ordered probit with sample selection as the most adequate method to explore determinants of production cost change. Ordered outcome models with selection are applicable for the discrete outcome whose values are naturally ordered, and a binary selection restricts data observability (De Luca and Perotti, 2011).

The selection equation dependent variable is the implementation of resource efficiency actions. It is a binary variable that takes the value 1 if a firm reports the implementation of any resource efficiency action in the past two years. The resource efficiency actions in the Eurobarometer survey include the following: saving water, saving energy, using predominantly renewable energy, saving materials, switching to greener suppliers of materials, minimizing waste, selling residues and waste to another company, recycling by reusing materials or waste within the company, and designing products that are easier to maintain, repair or reuse.

Independent variables in the models include the percent of turnover invested in resource efficiency, internal and external support to resource efficiency implementation, and problems encountered during the process. Models also control for the sector, market, and firm size measured by the number of employees and age. A list of the variables and their definitions is provided in Table 1.

Table 1: Description of the variables

Dependent variable		
Production costs change		1 = increase 2 = remain the same 3 = decrease
Selection equation dependent variable		
Implementation of resource efficiency actions		1 if the firm reports implementation of any resource efficiency action in the past two years
Investment in RE (% of turnover)	< 1%	1 if the firm invested less than 1% of annual turnover in resource efficiency over the past two years
	1 - 5%	1 if the firm invested 1% - 5% of annual turnover in resource efficiency over the past two years
	6 - 10%	1 if the firm invested 6% - 10% of annual turnover in resource efficiency over the past two years
	11 - 30 %	1 if the firm invested 11% - 30% of annual turnover in resource efficiency over the past two years
	> 30%	1 if the firm invested more than 30% of annual turnover in resource efficiency over the past two years
Support to RE implementation	Internal support	1 if the firm relies on its own financial and technical resources to be more resource-efficient
	Both internal and external	1 if the firm relies on both internal and external support to be more resource-efficient
Problems	Complex administrative or legal procedures	1 if the firm encounters complex administrative or legal procedures when trying to implement resource efficiency action
	Difficulty in adapting to environmental legislation	1 if the firm encounters difficulty in adapting to environmental legislation when trying to implement resource efficiency action
	Difficulty in choosing the right RE action	1 if the firm faced difficulty in choosing the right resource efficiency action
	Costs of environment action	1 if the firm faced costs of environmental action when trying to implement resource efficiency action
	Lack of environmental expertise	1 if the firm faced a lack of environmental expertise when trying to implement resource efficiency action
	Lack of supply	1 if the firm faced a lack of supply when trying to implement resource efficiency action
	Complex environmental labeling	1 if the firm faced complex environmental labeling when trying to implement resource efficiency action

Market	Services	1 if the firm sells only service
	Products and services	1 if the firm sells both products and service
Customers	Consumers	1 if the firm sells directly to consumers
	Companies	1 if the firm sells to other companies
	Public administration	1 if the firm sells to public administration
Sector	Retail	1 if the firm operates in the retail sector
	Services	1 if the firm operates in the services sector
	Industry	1 if the firm operates in an industry sector
Age	Years since the establishment	
Number of employees	Current number of employees in full-time equivalent	

RESEARCH FINDINGS

DESCRIPTIVE STATISTICS

The descriptive statistics presented in Table 2 show that most Croatian firms in the sample have implemented resource efficiency actions. To be precise, 93.61 percent of all firms implemented resource efficiency actions. They mostly implemented a combination of several resource efficiency actions. Almost 35 percent report many, while 33.45 percent report a few resource efficiency actions. The most prevailing resource efficiency action is the minimization of waste (67.81 percent), followed by saving energy (56.6 percent) and materials (52.26 percent). On the other hand, the least popular action is the use of renewable energy, which was applied by 10 percent of the firms.

All in all, firms in the sample reported rather extensive engagement in resource efficiency. This is surprising considering Croatia's overall low resource efficiency performance. This can be attributed to respondents' inclination to report desired behavior, potentially limiting research results and their interpretations.

Table 2: Descriptive statistics

		Percent of firms in the sample
Resource efficiency actions		93.61
Many actions		34.90
Some actions		24.41
Few actions		33.45
Production costs	Increased	25.39
	Unchanged	19.65
	Decreased	54.97
Investment in RE (% of turnover)	Nothing	13.22
	< 1%	34.36
	1 - 5%	39.65
	6 - 10%	7.71
	11 - 30 %	3.08
	> 30%	1.98

Most firms in Croatia invest between 1 and 5 percent of their annual turnover in resource efficiency actions. The percentage of those who invested more than 30 percent of their annual turnover in resource efficiency is remarkably low: less than 2 percent. It is worth noting that 13.22 percent of firms did not invest in resource efficiency actions in the two-year period. Over half of those reporting engagement in resource efficiency actions have decreased production costs. However, a closer look reveals that only 9.05 percent report significantly lower production costs. Approximately a quarter of the firms have higher production costs after accounting for the resource efficiency costs, while in almost 20 percent of firms, production costs remain the same.

RESULTS OF THE ORDERED PROBIT WITH SELECTION

Results of the ordered probit with selection are presented in Table 3. The presented model shows the most adequate specification compared to the alternative models assessed by the likelihood ratio test for comparing models. The Wald test indicates adequate model fit. The likelihood-ratio test shows that the null hypothesis stating that the errors for outcome and selection are uncorrelated can be rejected. Therefore, the ordered probit with sample selection is better for modeling the probability of production cost change than the simple ordered

probit model. Positive rho indicates that unobservables that increase the probability of production cost decrease tend to occur together with unobservables that increase the probability of implementing resource efficiency actions.

Results of the ordered probit with selection show that firms operating in retail and service sectors are significantly less likely to engage in resource efficiency activities than manufacturing firms. The probability of resource efficiency implementation in Croatian firms also significantly increases with the number of employees. The rest of the variables in the model on resource efficiency action implementation were not found to be significant.

Table 3: Results of the ordered probit with selection

Variable		Coefficients (St. errors)
Production costs change		
Investment in RE (% of turnover)	< 1%	.397 (.181)**
	1 -5%	.313 (.185)*
	6 - 10%	.169 (.250)
	11 - 30 %	-.348 (.355)
	> 30%	.257 (.360)
Support to RE implementation	Internal support	.098 (.201)
	Both internal and external	.100 (.260)
Problems	Complex administrative or legal procedures	-.095 (.124)
	Difficulty in adapting to environmental legislation	.146 (.157)
	Difficulty in choosing the right RE action	-.206 (.173)
	Costs of environmental actions	-.295 (.153)*
	Lack of environmental expertise	.127 (.142)
	Lack of supply	-.158 (.144)
	Lack of demand for RE products	-.144 (.153)
	Complex environmental labeling	.181 (.163)
Market	Services	.154 (.168)
	Products and services	.107 (.156)
Age		-.002 (.003)
Number of employees		.002 (.001)***

Variable		Coefficients (St. errors)
Selection equation – implementation of resource efficiency actions		
Sector	Retail	-.848*
	Services	-1.024**
	Industry	-.633
Customers	Consumers	.080
	Companies	-.279
	Public administration	-.240
Market	Services	-.125
	Products and services	.208
Age		.013
Number of employees		.009**
Constant		1.944***
No. of observations		429
Selected		397
Non-selected		32
Wald chi2 (22)		30.42
Prob > chi2		0.0467
rho		.754 (.109)
LR test of indep. eqns. (rho=0)	chi2 (1)	7.99
	Prob> chi2	0.0047

*Significant at 10 percent, ** significant at 5 percent, *** significant at 1 percent

As for the probability of production cost decrease, the analysis results reveal it is significantly influenced by investment in resource efficiency actions and costs of environmental actions. To be more precise, firms that invested less than 1 percent and between 1 and 5 percent of their turnover in resource efficiency action in the past two years are more likely to attain a decrease in production costs compared to those that did not invest in these actions. Higher investment in resource efficiency measured by the proportion of the turnover is not significantly related to production costs.

Furthermore, firms that encounter the costs of environmental actions as a problem are less likely to have lower production costs due to their engagement in resource efficiency actions. This variable does not measure exact costs or the costs relative to turnover. It indicates whether these costs were an issue while implementing resource efficiency actions. Regardless of the amount, the fact that firms encounter problems relating to the cost of these actions negatively

reflects the probability of lowering production costs. Problems other than those related to the costs of environmental action do not affect the probability of production costs decreasing.

The probability of production costs decreasing significantly increases with firm size. Namely, firms with more employees are more likely to benefit from resource efficiency action in terms of lower production costs. This finding aligns with previously cited literature on environmental practices that testify to the significance of firm size for implementing environmental actions. Considering that the structure of the firms in Croatia favors smaller business entities, the overall potential to benefit from resource efficiency actions in terms of production cost decrease remains limited.

The remainder of the variables in the model are not significantly related to the probability of production cost change. Interestingly, having full internal support or relying on both internal and external support relative to external support to resource efficiency action does not affect production costs.

To sum up, empirical results show that in Croatia, firms that invest less in resource efficiency actions relative to their turnover and those that do not struggle with covering the costs of this action are more likely to have lower production costs due to resource efficiency actions. The logic behind this relationship in Croatian firms seems simple: less investment and no problems with covering costs of resource efficiency actions lead to lower production costs. However, these findings point to the nature of resource efficiency actions. Although these are beyond the scope of this research, it is likely that resource efficiency actions implemented in Croatian firms are rather elementary and limited to regulation compliance.

From the business perspective, the rationale behind environmental legislation includes potential savings from resource-efficient solutions. However, this does not imply that all firms can decrease their costs, especially if they do not carefully consider how and when to implement the most adequate solutions. It is essential to approach these issues as a motive and a source of innovation. It is well-documented in the literature that environmental innovations bring the potential to improve firm performance (Doran and Ryan, 2012). The hypothesis that environmental innovation exceeds regulation compliance costs and improves business performance is known in the literature as the Porter hypothesis. Porter and van der Linde (1995) argue the importance of environmental legislation for developing or implementing environmental innovation, as firms often cannot foresee the potential benefits of environmental innovation for their business performance. The Porter hypothesis provides a framework for understanding how environmental regulations can foster environmental in-

novation that offsets the costs of complying with these regulations and helps firms improve their performance (Porter, 1991).

CONCLUSION AND FUTURE RESEARCH

This research reveals the main determinants of decreased production costs in Croatian firms.

According to the results, firms in Croatia that invest less in resource efficiency actions and do not struggle with the high costs of its implementation are likely to see some benefits from resource efficiency action, at least in terms of production cost decrease. However, these findings point to the nature of the resource efficiency actions implemented in Croatian firms. Much of the pressure to implement more resource-efficient behavior comes from the regulations and implementation of EU directives in national legislation, as the previous research on this topic in Croatia has shown (Zrnić, 2019). Let us suppose there is no strategic orientation toward more sustainable solutions, and any effort in that aspect is limited to regulation compliance. In that case, the benefits will be present only when expenditure is not too high.

These findings provide important implications for policy and practice. Policymakers should design adequate measures and support to help firms alleviate costs related to resource efficiency actions. This could also include subsidies and grants to help firms cover costs related to resource efficiency actions. Furthermore, managers should carefully consider adequate investment in resource efficiency, as more investment does not decrease production costs. A serious analysis is required in order to determine the amount of investment in resource efficiency actions.

It can be speculated that adding an element of innovation and novelty to this issue can be reflected in production cost change. The Maastricht Manual recognized the broad spectrum of novelty of eco-innovation. The bottom line is that it needs to be new or improved for the firm or the unit that implements it, and that it is superior to the practices used by the firm so far.

Furthermore, resource efficiency actions are, in their nature, environmental innovations with benefits in production. Extant research indicates that firms focused on environmental protection are inclined to environment-friendly solutions in both production and final use (Božić and Botrić, 2017). Green innovation is a moderator between environmental regulation and cost efficiency (Chan et al., 2016). Furthermore, Grekova et al. (2013) show that environmental process innovation mediates the relationship between environmental man-

agement and cost efficiency. Future research, therefore, can include various types of environmental innovation (in terms of novelty) in order to explain how firms benefit from resource efficiency. It can also be extended by adding a specific type of resource efficiency action and the level of its novelty to see if they produce different effects on production cost change.

The findings of this research are country-specific. They explain the relationship between resource efficiency actions and production costs in firms operating in a small country with low environmental performance. Further research on resource efficiency actions and the determinants of the decrease in production costs should explore if these findings are relevant to firms operating in other countries, especially those at the same level of environmental performance. Furthermore, a comparison with firms in other countries whose environmental performance is at a higher level is possible.

The benefits of resource efficiency practices can be evident immediately or shortly after their introduction. The present study explores the short-term change in production costs. The question of whether the effects will be evident immediately or if adequate time is needed to see production costs decrease remains for future studies. Another research avenue is in exploring how long firms can benefit from resource efficiency actions, especially keeping in mind the rebound effect. Production costs are only one aspect through which firms can benefit from resource efficiency actions. Positive effects on overall financial performance can exist even if the production costs increase or remain unchanged. As the literature review explains, environmental action can potentially improve other aspects of business performance. Future research can aim to extend the understanding of other benefits of resource efficiency actions for firms operating in Croatia.

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SPATIAL PLANNING AS A TOOL OF SUSTAINABLE TOURISM DEVELOPMENT – THE CASE OF CROATIA

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Tourism is a socio-cultural phenomenon that has experienced rapid growth in the last 75 years. In that period, the number of international tourist arrivals increased steadily worldwide. Such a trend brings many challenges for tourist destinations, and one of them is to provide accommodation and facilities for more tourists. However, that often leads to environmental devastation in tourist destinations. Violations of legal regulations and master planning frameworks during the construction of tourist infrastructure, also often without appropriate architectural designs, significantly contribute to degradation along coastal tourist areas. Mediterranean Europe is one of the most visited tourist regions in the world, and the negative impacts of tourism infrastructure development are visible in many countries of the region. Croatia is one of these countries, and it has a tradition of more than one hundred and fifty years of tourism development.

The paper aims to investigate the role of spatial planning in sustainable tourism development along the coastal area in Croatia. The methodology used in this paper focused first on a content analysis of the published scientific papers relating to spatial planning in tourism and sustainable development. In the second part of the paper, the available data and reports on spatial tourism planning in Croatia were analysed. The paper provides a critical view of the spatial planning models through the lens of the historical progression of illegal and unplanned construction practices within the tourism sector, along with their implications for tourism development in coastal Croatia. The research indicates that, despite the many years of existence of spatial plans in Croatia, there has been a persis-

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tent lack of implementation in tourist destinations along the coastal area, which has led to significant negative changes in the environment of some tourist destinations. The environment is one of the main resources for the tourism industry, therefore, careful planning and management of sustainable tourism development are essential for all efforts aiming to mitigate conflicts with land use. This paper can provide deeper insights into this issue, that could be useful for local tourist management. It also offers some suggestions for enhancing destination management in order to achieve long-term sustainable development. Hence, effective destination management is essential for minimizing the negative impacts of tourism on the surrounding ecosystem and preserving the environment.

Keywords: *Environment, spatial planning, sustainable tourism development, destination management, Croatia*

JEL: *01; L83; L88, Z32*

INTRODUCTION

Tourists are attracted to an area based on its space and tourism resources. In 2023, there were 1.3 billion international arrivals worldwide (UNWTO, 2024). However, the arrival of many tourists in those areas has resulted in numerous positive and negative outcomes. The positive impacts of tourism are manifested through additional stimulation of economic growth and development, support for small businesses, employment opportunities for young people, improved infrastructure, and preservation of sociocultural and historical heritage (León-Gómez et al., 2021; Mason, 2020; Pratama & Mandaasari, 2020; Uslu Alagöz & Güneş, 2020; Korry & Suarini, 2019). However, tourism development could also induce negative consequences such as overloading of infrastructure, pollution of waterways and the sea, irresponsible waste disposal, increased air pollution, noise, crowds, depletion of natural resources, loss of open space, the devastation of natural and cultural heritage due to excessive tourist visits, etc. (Klepej & Marot, 2024; Russo et al., 2020; Mason, 2020; Albalade & Bel, 2010; Petrić, 2011; Gartner, 1987). One of the growing problems in tourist destinations is the construction of tourist infrastructure, mainly consisting of numerous accommodation facilities built to ensure sufficient accommodation capacity for tourists. An increasingly evident problem in tourist destinations are secondary housing facilities – holiday homes. Such construction is often inappropriate and unplanned, and could lead to spatial

transformation, devastation and architectural visual pollution (Mason, 2020; Magaš et al., 2018). Those changes are mostly irreversible. That could lead to the loss of spatial resources, which is one of the reasons why tourists come to a certain destination. Tourism constantly and permanently transforms the space in which it takes place, which can result in dissatisfaction among tourists, and the local population as well (Gartner, 1987).

Tourism development, therefore, seeks a balance between minimising negative effects and preserving space as its basic tourist resource and the development which would assure benefits for all stakeholders in tourism (Liu, 2023; Grofelnik, 2019). Tourism can play an important role in preserving and protecting the space if it is planned on the principles of sustainability (Baloch et al., 2023). One of the tools for achieving long-term tourism development can be spatial planning (SP) because it simultaneously manages space in the long term and harmonises economic, spatial and social development based on space characteristics and market needs (Bartoluci, 2013; Risteskia, Kocевskia & Arnaudov, 2012). The UN defines spatial planning as “a key instrument for establishing long-term, sustainable frameworks for social, territorial and economic development and its primary role is to enhance the integration between sectors and to improve national and local systems of urban and rural development, also taking into account environmental considerations” (UNCE, 2008).

In some countries in Europe, SP emerged for the first time in the 1880s as a reaction to the inhumane housing and living conditions that arose primarily due to the rapid industry development (Čaldarović, 1987). In the 1960s, SP became the preoccupation of many European countries (Nichersu & Iacoboea, 2011). At that same time, faster tourism development occurred, and SP began to be applied in tourism development planning (TDP) (UNWTO, 2024; Parrinello & Bécot, 2019). Hence, for the first time, SP became an integral part of tourism development in the Languedoc-Roussillon region of southern France along a 200 km coastline (Côte d’Azur), with the aim to build 2 million new beds to provide accommodation for 45 million tourists by 1985 (Parrinello & Bécot, 2019).

In 1983, at the 6th Conference of the Council of Europe of Ministers Responsible for Spatial Planning (CEMAT), Resolution No.2 on The European regional/spatial planning charter (Torremolinos Charter) was adopted, representing the first such document in the history of regional/spatial planning at the European level, and setting out the main objectives for spatial planning policy in Europe (CEO, 1983). In 1999, the European Commission (EC) adopted the European Spatial Development Perspective (ESDP) to harmonise diverse spatial planning practices and to achieve more balanced sustainable

development across the EU (EC, 1999). In 2008, in cooperation with the UN, the EC adopted the document *Spatial Planning – Key Instrument for Development and Effective Governance*, which would indicate the benefits and importance of SP application in development planning to the governments (UNCE, 2008). In 2020, the EC adopted the *Territorial Agenda 2030 – A Future for All Places (TA)* as an additional incentive for EU countries to work on coordinating efforts and practices, and encourage inter-territorial cooperation, given that space knows no borders (EC, 2024).

Although strategic documents that define the basic guidelines of SP exist at the EU level, a unified spatial planning system does not exist in the EU. Nevertheless, each country has its spatial planning practices based on its specific spatial management system and legal and political context (Nadin et al., 2018; UNCE, 2008). Furthermore, every country is a unique area, specific by its natural and cultural characteristics which should be considered in SP and tourism development planning to achieve long-term development based on the principles of sustainability (Bučar, 2017). However, in all areas where SP is applied, it implies planned and regulated changes in land use which are based on recommended preparations aimed to achieve long-term optimal economic, socio-cultural and environmental effects (UNCE, 2008). In order to preserve the natural resources and local culture for future generations, destination management (DM) should apply sustainable practices and balance economic growth with environmental protection. This approach ensures that tourist activities do not exceed the capacity of the space. Thus, SP could be a good tool for DM so as to ensure sustainable tourism development (STD) in tourist destinations.

Tourism is one of the fastest-growing industries (Statista, 2024), and this paper examines the problems that can be observed in a tourist destination as a consequence of the increasing number of tourist arrivals. This paper aims to explain the role of implementing SP in STD. Following this introduction, a literature review of SP and STD is presented. In the second part of the paper, the documents that define SP and its role in tourism development in the coastal part of Croatia are examined. Finally, the paper concludes with a summary of the findings.

LITERATURE REVIEW

With the development of the economy and technological progress, the world is becoming increasingly aware of negative environmental changes. The issue of environmental protection at the global level was addressed for the

first time in 1972 at the UN Human Environmental Conference in Stockholm, where the Stockholm Declaration and Action Plan for the Human Environment were adopted. As a result of actions and agreements made at this conference, the concept of sustainable development (SD) was proposed in 1987 by the United Nations World Commission on Environment and Development (WCED) named “Our Common Future”, commonly known as the Brundtland Report (MVEP, 2024). This report defines sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Britannica, 2024). In 1992, the Conference on Environmental Protection, the United Nations Conference on Environment and Development (UNCED), also known as the “Earth Summit”, took place in Rio de Janeiro (SDGS-UN, 2024). During this conference, the fundamental document on environmental protection, the Action Plan for the 21st Century, known as Agenda 21 (Global Program of Action for Sustainable Development), was adopted with the aim to improve human lives and protect the environment (SDGS-UN, 2024). Since then, the concept of SD has become globally accepted, and in 2015, UN member states adopted The Agenda for Sustainable Development with 17 main goals whose implementation should ensure the long-term well-being of life on Earth (SDGS-UN, 2024).

Since the 1990s, the awareness and understanding of the tourism industry’s various positive and negative impacts on the environment have increased (Bučar, 2017). As a result, the tourism industry has also embraced the concept of SD as a method whose implementation finds a balance between ecological, socio-cultural and economic principles to ensure long-term development (UNWTO, 2024a). This approach is crucial not just for preserving the space in which tourism takes place (tourist destinations), but also for maintaining its position in the tourist market and attracting new tourists. The tourism market is dynamic and constantly influenced by changing demands and trends, hence, tourism should permanently adapt to those changes (Bučar, Hendija & Katić, 2022). According to WTTC in 2022, 69% of tourists will seek sustainable travel options in the upcoming years, and 75% of tourists plan to choose sustainable travel (WTTC, 2023). Tourists are increasingly seeking authentic experiences and preserved spaces during their travels, especially if they will contribute to the sustainable development of that area (UNEP, UNWTO, 2012; CREST, 2018). Such tourists tend to show loyalty and recommend these destinations to their friends and family (Frangos et al., 2015).

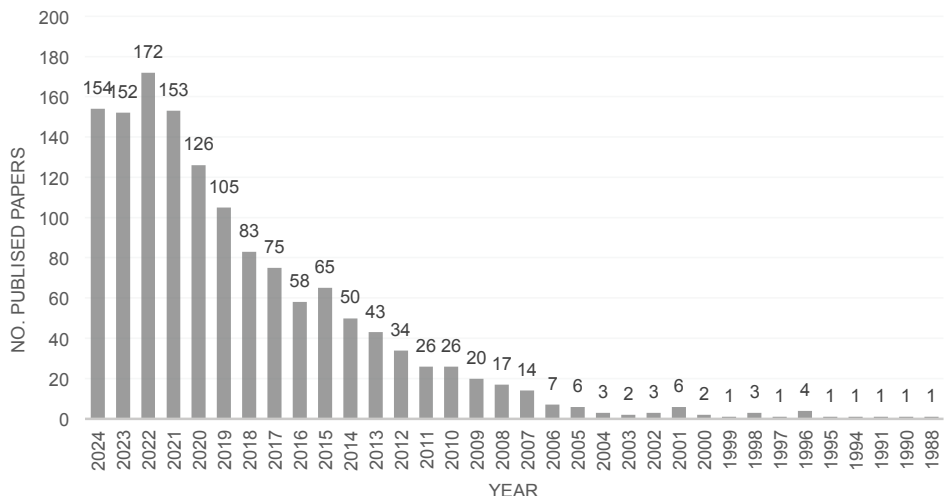
There are various instruments by which STD can be achieved, and SP could be one of them because the UN SP has 10 main goals, which include the following: “promote balanced social and economic development; reduce en-

vironmental damage; protect natural resources and natural heritage; enhance cultural heritage as a factor for development; etc...”, and which are almost identical to the goals of STD (UNCE, 2008; UNWTO, 2024a).

In order to accomplish the objectives outlined in this paper, a bibliometric analysis was conducted to gain insights into the representation of spatial planning in tourism in the scientific literature (Dabić, Mikulić & Novak, 2017). The research was performed on 20 November 2024, and includes an overview of all relevant articles indexed in the Web of Science (WoS) Core Collection since the mid-1950s when the electronic version of WoS was available. Content analysis was used to elucidate a timeline of the publication of scientific papers in the field of spatial planning in tourism (Dabić et al., 2017; Čorak et al., 2020). The approach aimed to comprehensively capture publications discussing these thematic areas, with the asterisk (*) operator allowing for the review of all lexical variations derived from the root words.

The initial part of this research concentrated on literature encompassing the concatenated terms “spatial* planning* tourism*”. The analysis of the obtained results showed that 1416 papers have been published in the field of spatial planning in tourism (Chart 1). The first paper was published in 1988 by the authors Kozłowski, J., Rosier, J. and Hill, G. under the title “Ultimate-Environmental-Threshold (UET) Method in a Marine Environment”. The following paper in this field of research was published in 1990 by author Wong, P.P., entitled “Coastal Tourism Development in Southeast Asia: Relevance and Lessons for Coastal Zone Management”, followed by authors Cooper, C. and Morpeth, N. in 1991 with “The Impact of Tourism on Residential Experience in Central-Eastern Europe: The Development of a New Legitimation Crisis in the Czech Republic”. In 1992 and 1993, there were no published papers, and after 1994, several papers were published each year. Since 2007, more than 10 papers have been published annually, and more than 100 papers have been published every year since 2019. The biggest number of scientific papers indexed in the WoS database was in 2022, with a total of 172. After that year, there was a decline in published papers. In 2023, there were 152 papers, showing a significant decrease in the number of published papers. The analysis of published papers was conducted on 20 November 2024, and by then, 154 papers had been published.

Chart 1: Number of published papers in WoS database from 1988 until 20 November 2024 – spatial* planning* tourism*

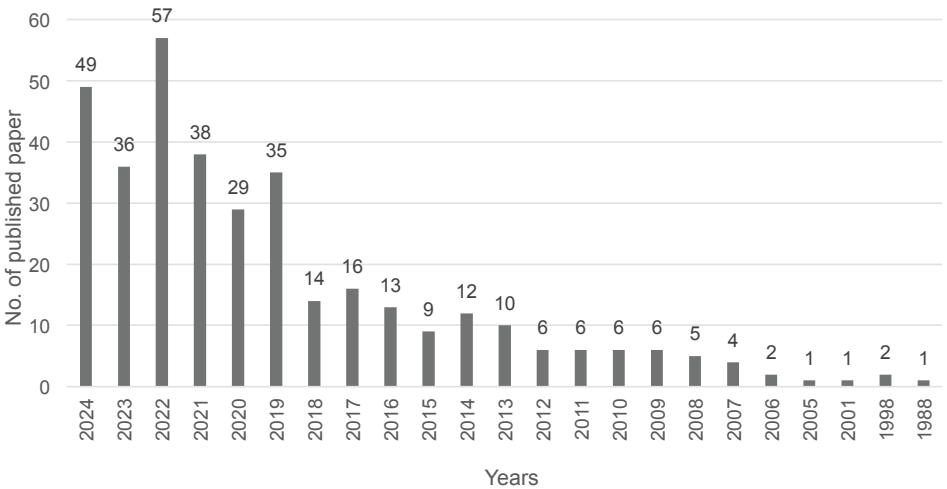


Source: <https://www.webofscience.com/wos/allldb/summary/89bacaf9-3713-4130-a211-5ed65752fd92-012f825c69/date-ascending/1>

The second step of the analysis focused on papers that included the terms “spatial* planning* tourism* sustainable* tourism* development*”. The results showed that 358 papers were published (Chart 2), significantly fewer than the number of papers published on the topic of spatial planning in tourism (Chart 1). Even the first paper addressing spatial planning in sustainable tourism development was also the first paper in the field of spatial planning in tourism (Chart 1 and Chart 2). As previously mentioned, it was published in 1988 by the authors Kozłowski, J., Rosier, J. and Hill, coming just a year after the term “sustainable development” was introduced. However, it took another ten years for the next papers on this topic to be published, which occurred in 1998. Starting in 2005, at least one paper on sustainable tourism spatial planning was published each year. Only since 2013 have more than ten papers begun to appear annually. In 2022, a record 57 papers in this research field were indexed in the WoS database. After that year, the publication of scientific papers in the field of spatial planning for sustainable tourism development decreased. Chart 2 reflects a trend similar to Chart 1, showing a decline in the number of scientific papers published in the field of spatial planning for tourism. This finding is unexpected, especially given that, in recent decades, sustainable development (SD) has been highlighted as the key approach for tourist destinations to

achieve long-term economic, environmental, and socioeconomic development (SDGS-UN, 2024; UNWTO, 2024a). Additionally, it is important to note that spatial planning (SP) shares the same objectives as sustainable tourism development (STD) (UNCE, 2008; UNWTO, 2024a).

Chart 2: Number of published papers in WoS database from 1980 until 20 November 2024 – spatial planning* sustainable* tourism* development**



Source: <https://www.webofscience.com/wos/woscc/summary/21a6790a-f21a-4d29-ab61-b6aa34a8baf0-0130f77b59/date-ascending/1>

The last phase of content analysis was conducted using the following keywords: spatial* planning* sustainable* tourism* development* Croatia*. The analysis showed that only eight scientific papers on the topic of spatial planning and sustainable tourism development in Croatia were published in the WoS database (Tab 1). The first paper appeared in 2009, and the last in 2019. Surprisingly, very few scientific papers exist in this field of research, especially considering that Croatia recorded 19.5 million tourist arrivals and 92.4 million tourists overnight stays in 2023 (CBS, 2024). Additionally, about 85% of tourist overnight stays occurred during the summer months, and approximately 90% were registered in the Adriatic (coastal) region of Croatia, which had 1.1 million beds out of a total of 1.2 million beds registered in the country that year (CBS, 2024). Consequently, all 7 published papers examine the role of spatial planning in achieving sustainable development in the Adriatic (coastal) region, often using smaller areas as case studies to highlight the importance of spatial planning for sustainable tourism development.

Table 1: Articles published in WoS database - spatial planning* sustainable* tourism* development* Croatia**

Author/s	Year	Journal	Title	Aim/Object of the paper
Jajac, N.; Kilić, J., Rogulj, K.	2019	Sustainability	An Integral Approach to Sustainable Decision-Making within Maritime Spatial Planning—A DSC for the Planning of Anchorages on the Island of Šolta, Croatia	the research examines economic, environmental, ecological, social, and civil engineering concerns related to the use of coastal water and it focuses on an integral approach to sustainable decision-making within maritime spatial planning
Poljanac-Borić, S.; Wetog, A.; Sikić, L.	2018	Tourism	Sense of place: Perceptions of Permanent and Temporary Residents in Croatia	the research provides an overview of literature and a policy discussion on second homes and the counter-urbanization process in Croatia – in the case of the island Šolta
Radeljak-Kaufman, P.	2017	Anales-Anali za istarske i Mediteranske studije	Scenario Making and Analysis in Spatial Planning: Scenarios of Spatial Development for Dalmatia until 2031	the paper aims to present the process of scenario design and analysis in spatial research and planning in the Dalmatia region in the period up to 2031, with an emphasis on sustainable tourism development
Kovačić, M., Favro, S. Mezek, V.	2016	Environmental Engineering and Management Journal	Construction of Nautical Tourism Ports as an Incentive to Local Development	the paper aims to determine the role of spatial planning in the recognition of development processes while respecting the interests of space and development opportunities for investors to determine the interdependence of nautical tourism development and development according to the needs of the City of Rijeka (Northern Adriatic)

Author/s	Year	Journal	Title	Aim/Object of the paper
Nižić, M.K.	2014	Tourism and Hospitality Management	Spatial Resources in the Development of Tourism Destinations (Case Study Kvarner)	the paper researches specific issues related to tourism and coastal urbanism which should be based on principles of sustainability, and include spatial alignment and overall development
Borsje, J. Tak, R.	2013	Tourism and Hospitality Management	The Regional-Local Nexus: a Landscape-Based Integral Design Strategy for Sustainable Tourism Development	the paper aims to investigate the relationship between landscape architecture and sustainable tourism development in the case of the city of Dubrovnik
Krstinić Nižić, M., Ivanović, S. Drpić, D.	2009	Economic Research	Spatial planning as the Function of Sustainability of the Island KRK	the paper researches the relationship between regional spatial planning and sustainable development on the most visited Croatian island – island Krk, and emphasises the importance of space as a tourist resource

Source: adopted by authors <https://www.webofscience.com/wos/woscc/summary/8283464e-13e7-488e-b3f5-f7e419b97f50-0130f895e6/date-ascending/1>

THE ROLE OF SPATIAL PLANNING IN TOURISM IN CROATIA

Modern tourism in Croatia started in 1868, when the Hygienic Association of Hvar was founded in Croatia (Vukonić, 2005). Until 1914, spas and thalassotherapy were the main reason for tourist arrivals in Croatia, and between the two World Wars, beach tourism began to develop (Vukonić, 2005). Since 1950, when 236,000 tourist arrivals were registered in Croatia, both the number of permanent beds and the number of visitor arrivals have steadily increased (CBS, 2023). Located primarily in the Adriatic coast region, Croatia had 43,000 permanent beds in 1950, with the numbers increasing to 863,000 in 1990, 961,890 in 2013 (the year Croatia joined the EU), and 1,150,436 in 2023 (CBS, 2024). The average tourist intensity rate in Croatia in 2023 was

2,386 tourist overnight stays per 100 residents and 30 permanent beds per 100 residents (CBS, 2024). Croatia's visitor density rate averaged 1,633 overnight stays per square kilometre in 2023 (CBS, 2024). The implementation of SP is essential in order to cope with such a large number of tourist visits and their impact on the area.

Croatia is one of the few countries with a long history of SP, and it can be traced back to the ancient times when the famous Diocletian's Palace, the first seaside villa in Croatia, was built during the Roman era (Hlača & Nakić, 2010). After that, the Dubrovnik Statute, issued in 1272, which testifies to the planned development of this part of the Adriatic coast over a long historical period, explained the continuity of spatial planning activities in this area (Rudež & Marić, 2014). The legal land management in Croatia can be traced from the Habsburg Monarchy when Empress Maria Theresa began regulating the land conditions in 1747 by enforcing the obligation to document local land conditions, which included the creation of a comprehensive land inventory with accompanying cartographic representations (Altić, 2014). After that, until after the Second World War, there were no attempts to legally resolve spatial planning, although the entire interwar period saw a massive construction of holiday homes without adherence to agreements and standards, characterized by rapid and extensive expansion (Kranjčević, 2012). The cost of paperwork for proper construction was far greater than the penalty for "illegal" construction, further incentivizing illegal development (Premerl, 1990). All architectural, spatial planning and construction activities were minimal during World War II (Kranjčević, 2021). However, in 1949, the general urban plans (GUP), also called local-level plans, were established as the fundamental urban planning document in Croatia (Tandarić, Watkins & Ives, 2019; MPUGDI, 2013). GUPs are a unique type of legal document adopted in Croatia at the state, regional and local levels, and each level of GUPs regulates and precisely defines certain tasks within the SP (OG 153/13, 65/17, 114/18, 39/19, 98/19, 67/23).

For the first time, SP for tourism in Croatia was used in creating the first regional spatial plan for tourism on the Croatian coast, entitled the "Regional Spatial Plan for the Makarska Littoral 1958-1961" (Kranjčević, 2021). It provided plans for the type and number of accommodation capacities, as well as the spatial distribution of the tourist buildings for this microregion, and it also warned of the possible long-term impacts of the construction of tourist infrastructure (Kranjčević, 2021). In 1960, a coastal area plan for Šibenik was drawn up, which was based on the tourist spatial plan for the Makarska Littoral (Kranjčević, 2021).

Table 2: *Spatial plans for the Adriatic coastal tourist region in Croatia until 1990*

Name of SP	Year	Geographical coverage
Southern Adriatic (<i>Južni Jadran</i>)	1968	the coastal plain of Montenegro, Bosnia and Herzegovina and the southern part of the territory of SR Croatia – from Split to Dubrovnik
Upper Adriatic (<i>Gornji Jadran</i>)	1970	the territory of SR Slovenia, the coastal and Alpine part (13 municipalities in SR Slovenia), and the northern area of SR Croatia from Split to Umag (33 municipalities in SR Croatia)
Adriatic III (<i>Jadran III.</i>)	1974	the coastal and island area of the Adriatic to the mountainous hinterland, the maritime zone and the hinterland in the gravity zone of large cities

Source: Mattioni, 2003; Kranjčević, 2021; Češljaš et al., 1988

The abovementioned SPs cover almost the entire Adriatic coastal tourist region of Croatia. After these, such spatial plans were no longer created for this or any other part of Croatia, although tourism in this area developed extremely quickly and strongly. Furthermore, these spatial plans were not used in tourism development planning in that region (Kranjčević, 2021).

After Croatia gained independence in 1991, the Croatian territory was divided into counties (20 counties and the city of Zagreb) in 1992, which served as the basis for the creation of SP at district, municipal and city levels (Kranjčević et al., 2014). In 1994, the Spatial Planning Act was adopted, which established the district spatial planning institutes (Leburić, Maroević & Šuljug, 2005). However, this Spatial Planning Act once again violated land policy mechanisms – private interests were brought to the fore while public interests were completely ignored (Leburić et al., 2005). After 2004, Croatia approved urban and municipal development by updating the Spatial Planning Act in 2013, 2017, 2018, 2019 and 2023, but that did not improve the situation (OG 153/13, 65/17, 114/18, 39/19, 98/19, 67/23; Jelinić, 2012). However, the problem at the local level is that many spatial plans were outdated considering the current socio-economic changes, such as the growth of private entrepreneurship and the real estate market (Hlača & Nakić, 2010; Kranjčević, 2021). Therefore, these spatial plans provide an opportunity to build as many square meters as possible on the smallest plot of land and make as much profit as possible without considering the consequences (Jelinić, 2012). This led to many buildings being registered in the land register and cadastre, and connected to the municipal infrastructure because they were built outside the parameters set in the permit or without building permits (Vetma, 2015). In Croatia, in

addition to GUPs and the Spatial Planning Act, other acts also regulate land management. There are the Environmental Protection Act (OG 80/13, 153/13, 78/15, 12/18, 118/18), the Act on the Treatment of Illegally Constructed Buildings (OG 86/12, 143/13, 65/17, 14/19), the Maritime Domain and Seaports Act (OG 158/03, 141/06, 38/09, 56/16, 98/19, 83/23), and the Construction Act (OG 153/13).

However, despite the existence of various acts and GUPs which regulate construction and, indirectly, the development of tourism, a variety of problems arose in the development of tourism in Croatia, especially in the construction of tourist infrastructure. This situation has arisen despite the existence of tourism development strategies in Croatia since 2003. The first Croatian tourism development strategy was implemented for the years 2003 to 2010, and it was followed by a strategy for the period from 2013 to 2020 (MINT, 2003; MINT, 2013). The first two strategies emphasize the importance of protecting resources that attract visitors to Croatia, but have not made significant progress. The most recent strategy was adopted at the end of 2022 and covers the period up to 2030 – the Sustainable Tourism Development Strategy from 2023 until 2030 (MINT, 2022). The current Sustainable Tourism Development Strategy strongly emphasises sustainable development in its title, highlighting that this approach is the only viable long-term option. In order to address the challenges of this development, the Tourism Act was introduced in Croatia for the first time, entering into force in 2024 (MINT, 2023). It regulates the activity of the participants in Croatian tourism, but also regulates the formulation of development plans and the assessment of tourism carrying capacity for each destination in Croatia (MINT, 2023). As these plans are still in development, it will take time to determine whether their implementation will result in positive changes for the area and halt the damage caused by tourism expansion.

DISCUSSION

Tourism as a sociocultural phenomenon is a form of “modern and peaceful invasion” (Railliet in Marinović-Uzelac, 1986). Such a situation is the result of rapid and sometimes unplanned development of tourism, which benefits the local economy by creating jobs, boosting the national economy and preserving cultural heritage, but also negatively impacts the local community, resources and socio-cultural structure (Petrić 2011; Wang et al., 2020; Uslu Alagöz & Güneş, 2020). Therefore, DM is a long-term process that aims to achieve a higher standard of living for the population, maintenance of the required eco-

logical level, and preservation of the cultural and historical heritage and its use for the economic and general development of the destination (Fyall & Garrod, 2020). However, unplanned tourism growth can lead to disputes between different stakeholders and sectors (Colavitti, Serra & Usai, 2018). Their interests may be similar but also opposite, which makes DM an extremely difficult process in practice. Thus, the main challenges of DM include stakeholder relationships and their integration to manage and maximize the “tourism experience” more effectively, while each of the stakeholders in tourism must assume its share of responsibility (Fyall & Garrod, 2020; Paskova & Zelenka, 2019). In addition, the local population is a crucial component of the tourism product, and if planning and development do not consider their needs and desires, resistance may arise, endangering the industry’s overall potential (Murphy & Murphy, 2004; Petrić, 2011). In order to promote SD, it is particularly crucial to involve the local population in the adoption of spatial plans and plans for the construction of new tourist capacities. This promotes the prudent use and preservation of spatial resources (Fyall & Garrod, 2020). However, local authorities often face the dilemma of whether to continue the economic development of their territory or to contribute to preserving the invaluable value of the pristine environment (Napierała, Leśniewska-Napierała & Cotella, 2022). Local governments should take an active role in promoting and implementing STD at the destination level (Birkić et. al., 2014; Salvador, Sancho, 2021). They need to create favourable conditions for the enforcement of laws and regulations established at the state level, including spatial planning (Masimba, 2024; Sitohang et. al., 2024). Additionally, local governments should provide extra support for sustainable tourism development through infrastructure development and maintenance, and also encourage the education of all stakeholders in the field of tourism, because it is unrealistic to expect that all stakeholders in tourism will be able to see all the consequences of their actions. Thus, local governments should take responsibility for developing destination management plans, promoting them, and ensuring their effective implementation.

In this regard, one of the main (long-term) development objectives of managing bigger social systems is to balance disparate interests and objectives according to sustainability principles (Petrić, 2011). In other words, the achievement of the intended development goals and accountability for SD depends on the collaboration and alignment of interests between the public and corporate sectors, as well as the civil society (Bartoluci, 2013).

Effective policies, DM and stakeholder accountability play an important role in mitigating the inevitable negative impacts of tourism. Specifically, the achievement of sustainability implies a change in the behaviour of all stake-

holders involved in tourism: tourists, tour operators and the hotel industry (Barišić & Bučar, 2022).

The research has shown that SP has similar goals to STD, therefore DM should pay more attention and include more SP in its activities. In addition, governments and local authorities should make additional efforts to educate all stakeholders, including those directly or indirectly involved in the tourism industry, so that they are aware of how unplanned construction of tourism infrastructure can negatively impact the environment and, therefore, the attraction of tourists and, ultimately, their livelihoods. Scholars should also provide additional knowledge to assist in this process. The SP in tourism is significantly represented in the global scientific literature, although with a decreasing trend. Given the many recent negative impacts on land, this issue should certainly be given more importance. This is particularly clear from the example of Croatia, and given the specifics of tourism and the numerous negative effects of tourism in the Croatian region, scientists should pay more attention to this issue.

The limitations of the paper lie in the fact that only secondary data sources were analysed and it focused on the analysis of published academic papers in only one academic database – WoS (although this is considered the most relevant database in the field of social research). The research should be extended to other databases. In addition, only spatial planning documents that directly affect tourism development in Croatia were examined. Therefore, in future research, it would be good to include an analysis of laws and regulations that seemingly do not directly affect tourism development, but are very important for its development and the preservation of the area. Additionally, it would be good to conduct empirical research among the local governments in Croatian coastal tourist destinations so as to assess their attitudes towards using SP as a tool in tourist destination management.

CONCLUSION

The growth of tourism as a socio-cultural and economic phenomenon brings about enormous opportunities and challenges, especially in environmentally sensitive regions like the Croatian coastal region. As tourists are drawn to those destinations for their natural and cultural resources, the role of effective DM becomes increasingly critical in their safeguarding. It requires constant effort among diverse stakeholders, including policymakers, local authorities, investors, and the local community, to balance the economic, environmental, and socio-cultural dimensions of tourism. In this process, DM still

does not recognise SP as a tool which has significant potential for mitigating the negative impacts of tourism while fostering its positive contributions.

Furthermore, scholars should make more effort in researching the role and potential of SP for the needs of tourism development, given the dynamic nature of tourism and its evolving trends. This would provide DM strategic decision-makers with additional knowledge that could help them manage tourist destinations based on the principles of sustainability. This is particularly relevant in areas such as Croatia, where the high concentration of tourists in coastal regions amplifies the urgency of aligning tourism growth with environmental preservation.

There is no doubt that there have always been many spatial plans in Croatia, but all these documents and laws did not deliver the expected results and achieved the desired goals. However, the example of coastal tourist destinations in Croatia suggests that the simple existence of SPs is not sufficient to simultaneously preserve land and achieve tourism development if they are not properly and completely implemented in practice.

Looking ahead, achieving long-term harmony between tourism and environmental sustainability requires not only robust planning frameworks, but also an inclusive approach that actively engages all stakeholders directly or indirectly involved in tourism. The main challenges in DM are in aligning the interests of all stakeholders in the tourism industry and embedding sustainability at the core of destination management. Public awareness campaigns and educational initiatives can foster a collective sense of responsibility. Therefore, achieving STD is an ongoing process that includes vigilant monitoring, proactive planning, and unified collective stakeholder efforts.

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THE RELATIONSHIP BETWEEN TRADE OPENNESS AND ECONOMIC GROWTH

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The goal of this paper is to contribute to the ongoing debate on the importance of trade openness for economic development. Our approach is to work within the framework of Schumpeterian growth models, emphasizing the importance of knowledge spillovers through the import channel (enabled by trade openness) and entrepreneurial activity for technological advancement. Using a fixed-effects panel model for modeling the impact of trade openness on economic growth for seven countries, we also test whether there is an impact of R&D investments on growth. Our results indicate a somewhat ambiguous positive effect of openness on growth. While one openness indicator supports the expected positive impact on growth, the other two indicators are statistically insignificant. Additionally, we observe an unexpected negative effect of changes in openness on growth, which may be attributed to short-term adjustment costs, and a significant positive impact of research intensity (spurred by entrepreneurial activity) on economic growth, in line with the Schumpeterian model assumptions. Interestingly, variables related to R&D did not show significance within the model, opening up space for further research and interpretations of the role of R&D in economic growth.

Keywords: growth, openness, tariffs, technology, R&D

JEL classification: O11, O30, O47, F43

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1 INTRODUCTION

The paper aims to examine the impact of trade openness on economic growth. This entails several considerations. The prevailing view in the literature has been that trade openness is a critical determinant of economic dynamics and growth, a notion so intuitive that the relationship between openness and growth was rarely questioned. However, the consensus on openness was disrupted by the work of Rodriguez & Rodrik (2000), which, among other things, questioned the prevailing methodologies for studying the impact of openness on growth.

The central question posed in this paper is the following: “What is the impact of trade openness on growth?” The accompanying question that arises from the central question is as follows (assuming technology drives growth): “Does R&D influence growth?”. Various economists have proposed differing ideas, but the common belief has been that the driver of technology is the investment in research and development (R&D), which produces new, high-quality products that improve the quality of life for economic participants. This perspective led to the creation of endogenous growth models where R&D investment is a central growth component, incorporating the knowledge spillover effect through import channels.

However, following the work of Jones, it became evident that the theory of endogenous growth contradicted empirical data, paving the way for new interpretations (Jones, 1995). Semi-endogenous growth models emerged, suggesting that R&D investment only has short-term effects on growth. Also, Schumpeterian models came into existence, which imply that R&D investments can have long-term effects on growth, provided that such investments increase proportionally with income.

The assumptions in this paper align with the Schumpeterian models, emphasizing knowledge spillovers and entrepreneurial activity as the drivers of technological growth. Following the work of Madsen, we focused particularly on how trade openness enabled knowledge transfers through imports and entrepreneurial initiatives to drive technological progress (Madsen, 2009). Our analysis employed a fixed-effects panel model across seven countries, using multiple indicators to measure trade openness while also examining R&D investment effects and research intensity on growth. The rest of the paper is structured as follows. The theoretical framework presented in the second chapter defines the theoretical relationship between the core variables of the study. The third chapter describes the variables, the sources of data collection, and the methods used to obtain these variables. The fourth chapter presents the

results of the panel analysis. Finally, the conclusion summarizes the findings of the study.

2 LITERATURE REVIEW

A recurring theme in economics over many years has been the consensus that openness facilitates and enhances economic growth (Madsen, 2009). This prevailing view among the economic and political circles, as well as within institutions such as the IMF, World Bank, and OECD, held that trade policies are among the most critical factors for promoting economic growth and convergence in developing countries. Moreover, Stiglitz argued that most research shows that any of the key indicators of economic openness (trade ratios, price indices, inverse tariffs) are strongly correlated with income growth (Stiglitz, 1993). Thus, traditional development literature considers exports as a stimulus to growth due to productivity-intensive spillovers from the tradable to the non-tradable sector, and because exports encourage more efficient investment projects (Edwards, 1993).

However, over the past two decades, a growing body of literature has emerged questioning the regression methods underpinning this consensus. Rodriguez and Rodrik, for example, argue that the positive correlation between openness and growth is not sufficiently convincing, given the various measures of openness and control variables used in previous research. They note that average tariff rates underestimate high tariff levels because they are associated with low import levels, while non-tariff barrier ratios are biased and insufficiently persuasive since they fail to adequately distinguish between barriers with minor and significant effects (Rodriguez & Rodrik, 2000).

Furthermore, if we consider the methodology of classical growth models that incorporate technology, such as Solow's, assumptions of the absence of market imperfections and other distortions are present. Under such conditions, the relationship between openness and growth is positive. However, if externalities are considered, trade restrictions can increase income.

On the other hand, endogenous growth literature has shifted the argument on how openness drives growth by focusing on the import of knowledge (Coe et al., 2008; Rivera-Batiz & Romer, 1991). Barro and Sala-i-Martin argue that imports provide domestic producers with access to a broader array of capital goods, thereby increasing production efficiency (Barro & Sala-i-Martin, 1995). Imported technology enhances labor productivity in the importing country and fosters domestic productivity growth.

Since technology is fundamental to endogenous growth models, the assumption of knowledge transfer through the import of technologically advanced products implies that openness will influence growth to the extent that the importing country trades with research-intensive economies. The conclusion of such models is that, with imitation costs lower than innovation costs, a smaller country will converge toward a larger one.

However, even within endogenous growth models, there is a scenario where trade barriers positively impact economic growth. This could occur in subsets of countries that had favorable capital investments and were at a certain level of technological development during the observed period, reducing the need for further imports in subsequent periods. Such a case might arise when an importing country with a non-dynamic technological sector is incentivized to produce rudimentary goods, subsequently experiencing a lower growth rate. Additionally, if the technological gap between the importing and exporting countries is substantial, the importing country may lack the capacity to absorb the technology. This leads to the conclusion that homogeneity within the sample of countries is critical in models addressing openness and growth. Moreover, as this study follows the Schumpeterian framework, an additional variable is research intensity driven by entrepreneurial activity, which is a core assumption in such growth models.

3 EMPIRICAL FRAMEWORK

There is a significant amount of literature discussing the impact of trade openness on growth, with a lot of the research being dictated by variables used for proxying trade openness. For example, Edwards ran a robustness analysis between TFP and growth, using nine different indicators for openness¹ (Edwards, 1993). The paper concluded that there was a significant positive relationship between openness and growth. However, Rodriguez and Rodrik argue that the evidence provided in favor of those claims is significantly lacking in

¹ Those indicators were: 1) the SW openness index; 2) the World Bank's subjective classification of trade strategies in World Development Report 1987; 3) Leamer's openness index, built on the basis of the average residuals from regressions of trade flows; 4) the average black-market premium; 5) the average import tariffs from UNCTAD via Barro and Lee; 6) the average coverage of nontariff barriers, also from UNCTAD via Barro and Lee (1994); 7) the subjective Heritage Foundation index of distortions in international trade; 8) the ratio of total revenues on trade taxes (exports + imports) to total trade; and 9) Holger Wolf's regression-based index of import distortions

evidence as the econometric methods were problematic² (Rodriguez & Rodrik, 2000). The study also reported that trade tax ratios, calculated from IMF data, appear implausible, particularly for developing countries like India, which is listed with a surprisingly low ratio despite high tariff rates³. Critics conclude that there is not enough evidence for an unambiguous relationship between openness and growth.

Frankel and Romer address the endogeneity of trade with respect to income by instrumenting trade shares using a gravity model based on geographic characteristics. Their main finding is that the instrumental variable estimate of trade's effect on income is greater than the OLS estimate. However, further analysis suggests that geography, through channels such as public health, institutions, and natural endowments, significantly influences income beyond its impact on trade. When additional geographic variables are included, the instrumental variable estimates on trade become statistically insignificant and fall below the OLS estimates, indicating that non-trade geographic factors are likely the primary drivers of the observed relationship between trade and income (Frankel & Romer, 1999).

Our approach is based on the work of Madsen, who modeled the impact of trade openness on economic growth for 16 OECD countries for the period 1870-2006 (Madsen, 2009).

The analysis was conducted using a fixed-effects panel model on a group of seven countries: China, Germany, France, Japan, South Korea, the United States, and the United Kingdom – over the period 2000–2019. The dependent variable in the model is total factor productivity (and alternatively per capita output), while the independent variables include trade openness, the year-on-year change in trade openness, domestic knowledge stock, foreign knowledge spillovers through import channels, and research intensity:

² Edwards accounts for heteroskedasticity by weighting observations based on GDP per capita, assuming that the standard deviation of growth disturbances is inversely proportional to the square root of GDP per capita. However, this assumption implies unreasonably high errors for poorer countries, raising doubts about the reliability of the growth data and the validity of conducting regression analysis on such a dataset. They argue that the best way to approach the alternative assumptions regarding the nature of the skedastic function is to use White's heteroskedasticity-consistent standard errors.

³ Using more reliable World Bank data, alternative calculations show much higher and more plausible trade tax ratios, but these revisions yield inconsistent results in regression analyses—import duties often have positive and insignificant coefficients, while export duties remain insignificant. Overall, the findings suggest little evidence that simple averages of trade taxes are significantly and negatively correlated with economic growth, highlighting the limitations of small sample sizes and data discrepancies.

$$\ln TFP = \alpha_0 + \alpha_1 Op_{it} + \alpha_2 \Delta Op_{it} + \alpha_3 \Delta \ln S_{it}^d + \alpha_4 \Delta \ln S_{it}^f + \alpha_5 r + TD + \varepsilon_{1,it} \quad (1)$$

Trade openness (*Op*) refers to a variable that attempts to determine the degree of a country's openness to trade. In this study, it is proxied by three different indicators: inverted weighted mean applied tariff rate, trade-to-GDP ratio, and import-to-GDP ratio. The data used for obtaining the indicators was acquired from the World Bank database.

In the literature, trade barriers and import penetration are used as indicators of trade openness, with the caveat that no universal measure of trade openness exists. The theoretical literature places greater emphasis on the relationship between trade policies and income growth than on the direct link between trade and growth (Yanikkaya, 2003). Furthermore, there is no clear consensus on what constitutes openness or what is meant by trade openness and liberalization. The relevant literature primarily focuses on import penetration; however, Rodríguez and Rodrik argue that import penetration is not an adequate measure of trade barriers and propose using trade openness as an alternative (Rodríguez & Rodrik, 2000). Trade openness specifically captures trade barriers, whereas import penetration is influenced by numerous factors unrelated to trade barriers and can, therefore, be an unreliable indicator in this context.

As Madsen claims, another issue concerns the exogeneity of trade barriers and import penetration. The literature on endogenous tariffs consistently asserts that tariffs are determined by internal forces. Additionally, import preferences are significantly influenced by economic conditions. It turns out that countries adopting free-market trade policies often simultaneously implement stable monetary and fiscal policies. Consequently, the effects of tariff policies on income in regression analyses may yield ambiguous results due to the influence of other policies not included in the regressions (Rivera-Batiz & Romer, 1991). Therefore, based on the available literature, we will proxy trade openness by inverted weighted mean applied tariff rate, trade-to-GDP ratio, and import-to-GDP ratio of each country in the panel.

In the literature on growth, research and development (R&D) functions as a primary driver of economic growth through innovation generation and productivity enhancement. Data demonstrate the direct correlation of R&D with technological advancement and sustained per capita GDP growth with the mechanism operating via knowledge accumulation and skill development within systems, establishing critical infrastructure for economic development (Ulku, 2004). However, empirical testing of endogenous growth models primarily examines R&D effects on TFP growth. Jones reports no positive correlation between TFP growth and scientist/engineer growth rates in major

economies, but Aghion and Howitt attribute this discrepancy to technological complexity and product proliferation diluting the individual innovations' impact on aggregate knowledge (Aghion & Howitt, 1992; Jones, 1995; Madsen, 2008). They propose that the GDP share of R&D investment is a more accurate metric than researcher quantities, accounting for economic scale effects. Multiple other studies demonstrate positive R&D-TFP growth correlations, particularly in the U.S. economy (Griliches & Lichtenberg, 1984). Zachariadis also identifies stronger R&D effects on aggregate output compared to manufacturing-specific impacts (Zachariadis, 2003).

In the work of Ulku, data indicates heightened R&D effectiveness in large-market advanced economies, particularly G-7 nations, attributable to established R&D infrastructure and market scale advantages (Ulku, 2004). However, the R&D-innovation relationship exhibits diminishing marginal returns, contradicting assumptions of constant innovation returns. It is also very important to note that less R&D-efficient economies demonstrate significant dependence on international technology spillovers for innovation advancement. This phenomenon emphasizes the role of cross-border knowledge transfer and trade relationships in technological diffusion. In the same work, the R&D sector exhibits increasing returns to scale, enabled by non-rival knowledge stock characteristics, thus allowing output expansion without proportional input increases, as existing knowledge assets enhance production efficiency. For the growth to be sustainable, economies require systematic R&D investment coupled with human capital development (linked with education, but outside the scope of our work). The interaction between domestic R&D capacity, international knowledge transfer, and human capital formation creates a complex system driving innovation and economic advancement (Ulku, 2004). The data demonstrate that R&D effectiveness operates through multiple channels: direct innovation production, knowledge spillover effects, and human capital enhancement. These mechanisms interact synergistically, amplifying R&D's contribution to economic growth beyond direct innovation outputs.

However, an R&D data analysis solely based on inputs (expenditure), while informative for endogenous growth theory validation, exhibits limitations due to its lack of focus on innovation outputs. Our work, therefore, aims to establish a connection between openness and R&D not only through domestic R&D expenditure but also through knowledge spillover (by the means of trade) and research intensity (R&D output).

Therefore, in this work, foreign knowledge spillovers () represent knowledge transferred into a country via the import of technologically advanced products. This variable seeks to model the theoretical assumption that not all

knowledge must be created domestically. Instead, knowledge can also be imported through high-quality products that subsequently stimulate the growth of domestic products within the same industry, which is extremely useful for countries lacking efficiency in R&D sectors (which is in line with the premise that innovation is endogenously created). The calculation of α is based on World Bank data, starting with the percentage of imports from each trading partner for each country in the model. This percentage is then multiplied by the R&D investment of the exporting countries as a percentage of their GDP. For each year, these values are weighted by the GDP of the exporting country so as to avoid volume bias, as larger countries naturally invest more in R&D in absolute terms than smaller countries. This process is repeated annually for each observation (Coe et al., 2008; Wei & Liu, 2006).

Research intensity (r) refers to the intensity of research within an economy, closely linked to entrepreneurial creation, which is a hallmark of Schumpeterian models. The underlying assumption is one of creative destruction, where new entrepreneurial activities displace the existing ones. This occurs as new, higher-quality products replace older, inferior ones.

While the use of patent data in macroeconomic analysis of innovation is relatively recent, it has long been a common tool in microeconomic studies. Notable contributors such as Hall, Griliches and Hausman, and Hall, Jaffe and Trajtenberg have utilized sector-level patent data to analyze innovative activities (Hall et al., 1986).

In this model, the variable r is measured by dividing X , the annual number of patents (World Bank), by Q , the size of the labor market (World Bank). The calculation takes into account the implication in Schumpeterian models that research and development activity corresponds to the number of employees, which in turn is determined by population growth. This metric captures the idea that the scale and success of R&D activity depend on the workforce size, reflecting the dynamic interplay between innovation, labor, and economic growth.

Besides the presented variables, the model employed a two-way fixed-effects approach to control for unobserved country-specific and time-specific effects. This framework accounted for inherent differences between countries and common shocks over time, ensuring that the estimated relationships between trade openness, knowledge stock and spillovers, research intensity, and economic growth were not biased by omitted variable concerns. The time-specific effects were included so as to capture the effects of major economic disruptions such as the Global Financial Crisis (GFC) and the euro area crisis. Lastly, as we are trying to measure the rise in productivity, our dependent variable is TFP, as it should theoretically paint a better picture than GDP would.

4 RESULTS

The results where $\ln TFP$ is the dependent variable are presented in Table 1. Three different openness indicators are presented in the columns.

The regression model using an inverted weighted mean applied tariff rate as an openness indicator explains 42.05% of the variance in the dependent variable, as indicated by the R^2 , with an adjusted R^2 of 25.07% accounting for the number of predictors. The F-statistic (14.3677) and its highly significant p-value (1.4413×10^{-10}) confirm that the overall model is statistically significant and provides a good fit for the data.

The regression model using the trade-to-GDP ratio as an openness indicator explains 31.21% of the variance in the dependent variable, as indicated by the R^2 , with an adjusted R^2 of 11.84% accounting for the number of predictors. The F-statistic (9.34847) and its highly significant p-value (2.2863×10^{-7}) confirm that the overall model is statistically significant and provides a good fit for the data.

The regression model using the imports-to-GDP ratio as an openness indicator explains 28.81% of the variance in the dependent variable, as indicated by the R^2 , with an adjusted R^2 of 8.77% accounting for the number of predictors. The F-statistic (8.33774) and its highly significant p-value (1.1969×10^{-6}) confirm that the overall model is statistically significant and provides a good fit for the data.

Table 1: $\ln TFP$ as a dependent variable

Openness indicator	Inverted weighted mean applied tariff rate	Trade-to-GDP ratio	Imports of goods and services-to-GDP ratio
Op	1.214578 ***	0.00055	0.00061431
ΔOp	-1.422285 ***	-0.00292997 **	-0.00444983 *
$\Delta \ln S^d$	0.02615	-0.01965809	-0.0217897
$\Delta \ln S^f$	0.007034	0.00935713	0.00895809
r	28.842014 ***	34.06700762 ***	31.53359907 ***

The coefficient for the level of trade openness is positive, aligning with the theoretical frameworks of the past few decades in international economics and growth theories. This positive relationship supports the widely accepted view that greater openness fosters economic growth by enhancing market access, competition, and knowledge spillovers. The magnitude of the effect suggests that if the inverted tariff rate increased by 1% it would lead to a 1.21% increase in TFP, which signals a clear positive impact of trade openness on trade growth. Regarding the other two models (with different openness indicators) – their openness coefficients are not significant.

However, a negative coefficient for the one-year change in openness in the first column is less intuitive and somewhat surprising. The result suggests that a 1 percentage point increase of the one-year change in inverted tariff rate leads to a 1.42% decrease in TFP. Several potential explanations exist for this unexpected finding. One possibility is that abrupt increases in trade openness may temporarily disrupt economic activity (lag effects in economic adjustments), leading to short-term negative effects that outweigh the long-term benefits of openness. As we use the two-way fixed effects model, we conclude that explanations for this disruption, such as omitted variable bias or lack of control variables, are not viable. Therefore, such disruptions might stem from structural adjustments, resource reallocation, or heightened competition that could harm less competitive domestic sectors in the short run.

In the model with a trade-to-GDP ratio as our openness indicator – the coefficient for change in openness is less significant than in the previous model, but still significant. Its economic impact is significantly lower, effectively neutral, nevertheless still negative. In the last model, the coefficient is moderately statistically significant, and its economic impact is also effectively neutral, but negative.

The results are more interesting, knowing that Madsen's results in the comparable period are also in contradiction, but in a converse manner – as our estimated coefficients for openness are positive, his are negative. Our estimated coefficients for change are negative, and his are positive. It should be kept in mind that his change in openness implies a five-year operator and ours a one-year operator.

The coefficients for the domestic stock of knowledge and the foreign knowledge spillovers are not statistically significant in any of the three models, and therefore, we are not able to establish an additional relationship between trade openness and economic growth through the channel of imports (knowledge spillover), which was one of the goals of the research. The interesting thing about the results is their contrast with Madsen's (with his referent period for the comparison being 1956-2006). His results indicate that knowledge spillovers play a crucial role in driving economic growth through trade openness. The coefficients for foreign knowledge stock via imports are consistently positive and significant, suggesting that openness fosters temporary growth effects when trading with knowledge-intensive countries (Madsen, 2008).

The coefficient for research intensity is highly statistically significant, and its impact on economic growth is extremely important in each of the models. However, establishing causality for this variable remains challenging, as is often the case when analyzing economic growth. Nonetheless, conclusions can

still be drawn based on intuition. In this context, it appears fairly logical that research intensity within an economy plays a crucial role in driving long-term economic growth. Of course, the relationship between the two variables is also cyclic in nature – just as research activity can play a factor in influencing economic growth, economic growth can also, in turn, play a factor in positively influencing research activity (the aforementioned causality problem). However, research activity being this high of a growth driver fits into the Schumpeterian framework (as a measure of R&D output). Taking into consideration the short-term disadvantages of using R&D expenditure-based data as we did for the domestic knowledge stock and knowledge spillovers, research intensity deals with R&D in a longer time frame (it takes more time for a patent to get applied and confirmed than merely spending a part of the budget on R&D). For this reason, we can claim that trade openness positively impacts economic growth through the channel of imports by growing the technology base in the importing country and impacting the knowledge base of the economy. This effect occurs as technologically advanced imports facilitate the transfer of knowledge and innovation, enabling domestic industries to improve productivity and efficiency. Moreover, these imports can act as a catalyst for domestic innovation by fostering competition and providing access to superior intermediate goods and production technologies. Over time, this dynamic contributes to sustained increases in TFP and supports the broader economic development of the importing country. Our results are in line with those of Madsen, as his estimated coefficients of research intensity are also highly significant and positive (although our coefficients are significantly larger). Additionally, disregarding the trade implications, research intensity seems to be the driver of technology growth inside an economy, i.e. it would make more sense to encourage entrepreneurial activity inside an economy than to boost knowledge stock by way of trade.

5 CONCLUSION

This study examined the impact of trade openness on economic development through the lens of Schumpeterian growth theory, contributing to the ongoing debate on the role of trade openness and R&D in driving economic growth. Following the works of Madsen, we focused particularly on how trade openness facilitates knowledge transfers through imports and entrepreneurial initiatives, fostering technological progress.

Our analysis employed a two-way fixed-effects panel model across seven countries, using inverted tariff rates, trade-to-GDP ratio, and imports-to-GDP

ratio in order to measure trade openness while also examining the effects of R&D investment and research intensity on growth. The findings revealed that higher levels of trade openness corresponded with increased growth, although changes in openness surprisingly exhibited a negative correlation – possibly due to the short-term adjustment costs.

The results also demonstrated that research intensity, driven by entrepreneurial activity, significantly boosted economic growth, aligning with Schumpeterian model predictions. Notably, research intensity proved to be more influential than domestic R&D spending, suggesting that policymakers should prioritize fostering entrepreneurship over direct subsidies to R&D. This reinforces the idea that innovation and technological progress thrive in environments that encourage dynamic market-driven research rather than relying solely on state-funded initiatives.

While our findings confirm that trade openness positively impacts growth through knowledge imports, the lack of significance in certain R&D-related variables presents an intriguing avenue for future research. In particular, further differentiation between domestically funded R&D and imported R&D could provide deeper insights into how various innovation mechanisms contribute to economic development.

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PUBLIC-PRIVATE PARTNERSHIPS FOR SUSTAINABILITY IN CROATIA: A COMPARATIVE ANALYSIS OF MODELS AND LESSONS FOR THE FUTURE

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Public-private partnerships (PPP) are long-term, contract-based collaborations between public and private enterprises. These actors enter partnerships to combine their strengths and capabilities and create sustainable infrastructural projects for delivering public goods and services. They are envisioned as a way to make use of the expertise, technologies and efficiency of private companies, alleviating the managerial and budgetary constraints that stifle the development of new projects by public enterprises. In PPPs, these actors share both the risks and benefits in order to align the interests of all stakeholders, aiming to provide reliable long-term services. Because of their usability and beneficence to society, regulators worldwide analyse different PPP models with the aim of developing regulatory frameworks and guidelines to make such partnerships maintainable. For example, the World Bank PPP Reference Guide elaborates on the importance of risk management, suggesting more risks should be borne by the private partner and their remuneration should be based on performance outcomes. The European PPP Expertise Centre classifies three types of payment sources for potential PPP creators to consider – the government, the public service users, or both, depending on the type of project. These suggestions are oriented towards the aim of making the provision of public goods and services tenable in the long run, as most of

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these projects are developed with the aim of being stable and beneficial for a long period of time.

The PPP model has the potential to address some of the most pressing global challenges today, including economic growth, waste management, or green economics, by enabling the creation of sustainable infrastructures which address and serve the public interests. However, while PPPs can offer solutions to complex public service challenges, they require robust contractual frameworks and carefully structured, custom-made risk-sharing solutions to succeed. Variants of PPP models such as DBFOM (Design, Build, Finance, Operate, Maintain), BOT (Build, Own, Transfer), or BTO (Build, Transfer, Operate) each require different project stages, asset ownerships and risk allocations. For example, when applying a BOT model, the private sector partner assumes project ownership until the end of the contract term and carries the financial and operative risks. In this arrangement, the public partner takes over the ownership after the contract expires. Their differences underscore how varied and complex the structuring of agreements and plans for PPPs can be when aiming to secure their individual success and long-term use.

With this article, we aim to contribute to the knowledge and development of public-private partnerships in Croatia, a small economy with a great need for sustainable public infrastructure development. Croatia has only had a limited number of public-private partnership agreements so far, which have been quite varied. This study aims to systematically assess Croatian PPP projects against the different PPP models, in order to evaluate important factors such as financing, risk allocation, and stage planning. This can be performed through a content analysis of all PPP projects and their contracts established in Croatia so far, which are publicly available in an online repository made available by the Croatian Ministry of Economy. By comparing the models of Croatian PPPs with each other and with the common PPP models and best practices, this research identifies their advantages and pitfalls, thus providing a basis for recommendations so as to optimize future PPP agreements towards sustainability.

Keywords: *Public-private partnerships, economic growth, infrastructure development, sustainable public services, regulatory economics*

JEL classification: *H30, H40, H41, H43, H54*

INTRODUCTION

A public-private partnership (PPP) is a model that enables the satisfaction of needs for public goods and services, such as infrastructures, public transportation, education or construction, by fostering cooperation between public and private partners and utilizing their respective advantages. The proponents of this model argue that private partners' technology, innovation and expertise help to improve the quality of public goods and services while easing the budget constraints of public spending. In times when European governments require significant funds to fulfil their commitments to energy transition, circular and net zero carbon economy and creating local, self-sustainable communities, the PPP model is becoming increasingly appealing as it provides workable solutions to these concrete issues. They represent particularly relevant options for solving large infrastructure gaps, as global infrastructure investment needs are expected to reach 94 trillion dollars by 2040 (Global Infrastructure Outlook, 2024). However, such cooperation of public and private sectors, if mismanaged or misaligned, might prove to be costlier, riskier and ultimately unsuccessful. Due to this, different institutions such as the World Bank and the European Investment Bank have created guidelines for companies and policymakers to ensure the quality and appropriateness of proposed PPP projects (European Investment Bank, 2021; World Bank Group, 2017).

Croatia has a relatively developed framework for instituting PPP projects. This is evidenced by the existence of the legal framework, the Croatian Public-Private Partnership Act (Public-Private Partnership Act, 2015). Furthermore, the importance of PPPs is recognized and mentioned in several government documents, such as the Croatian National Housing Policy Plan until 2030, and the Croatian Low-carbon Development Strategy until 2030 with an outlook to 2050 (Croatian Parliament, 2021). Croatia has had 17 public-private partnership projects, at a total valuation of about EUR 338 million (Ministry of Economy, Entrepreneurship and Crafts, n.d.), most of which are still ongoing. In 2019, the Croatian Ministry of Economy took over the approval and monitoring of any further contracts from the PPP Agency, indicating a possible inefficiency of PPP use in Croatia. Even less discussed is the issue of the sustainability of PPP projects in Croatia (Mašović et al., 2024). Public-private partnerships are closely related to the sustainable development of countries, societies and the environment, as they are deeply involved in infrastructure development. Thacker et al. (2019) demonstrate that PPPs are relevant for many of the sustainability targets, including SDG 3 (good health and well-being for

all), SDG 6 (clean water and sanitation), SDG 7 (affordable and clean energy) and SDG11 (sustainable cities and communities).

There is a growing scholarly interest in the relationship between PPP and sustainability (Castelblanco et al., 2021; Castelblanco & Guevara, 2022; Narbaev, 2022, 2022; Nizkorodov, 2021; Wang et al., 2018), and an unresolved and much-discussed issue is that of the relationship between the defining features of PPP models and the sustainability of PPP projects. This article joins the interest by analysing PPP contracts in Croatia, discussing their model uses and specifically private-public risk allocations, and relating these results to their implications on the sustainability of these projects. It thus contributes by presenting a comprehensive inquiry into all PPP contracts in Croatia, showing what we know and what we can expect from these PPP projects in relation to sustainability.

The paper is divided into six sections. The following section presents a literature overview of what PPPs are and what are some of their main elements, and constructs a reference table of the most common PPP contract models. This is followed by a description of our methodological approach, while in the fourth section, the results of the analysis of Croatian PPP contracts, that is, projects, are presented and described. This is followed by a discussion of the implications of the models for sustainability, ending with the conclusion of the paper.

LITERATURE REVIEW

PPP MODELS

Public-private partnerships are contractual models generally designed for national infrastructure projects. According to the literature review conducted by Wang et al. (2018), the predominant definition of a public-private partnership (PPP) is that it is a complex, long-term cooperation between public and private sectors with the goal of constructing infrastructure and providing public services. Additionally, all partners should share the risks and benefits with the aim of achieving their own, as well as common goals – the latter being the creation of public value. This definition is closely aligned with the PPP Reference Guide (World Bank Group, 2017), further elaborating on the risk and profit management. It states that the private partner should bear significant risk and management responsibility where remuneration is linked to performance. Another institution that is relevant to defining the PPP structure is the

European PPP Expertise Centre, which stresses the sources of payments. The following three sources are identified: the service users, the contracting authority or government, and a combination of both (European Investment Bank, 2021). Due to the complexity and nature of such projects, which are more risky than conventional public procurements (Wang et al., 2018), there is an effort for the standardization of such partnerships. PPP reference guides and expertise centres have been established to suggest custom-based models for distributing financing, asset ownership, or risk management in such projects (World Bank, 2023). Effective PPPs are based on well-thought-out contracts (Meissner, 2019).

The World Bank, in cooperation with institutions around the world, has recognized and described several different models of PPPs based on their common parameters (World Bank Group, 2017). For ease of understanding and for later analysis, two tables of PPP models and contract characteristics are presented based primarily on the PPP reference guide by the World Bank, enhanced with insights from Wang et al. (2018). In the PPP reference guide, concessions that satisfy the conditions of longevity and provision of public service are also proposed as a type of PPP (World Bank Group, 2017). However, concessions are regulated by a separate legal Act in Croatia and defined differently than PPPs, therefore they have been excluded from the analysis for this research paper.

Table 1: Public-private partnership contract model types

Model type	Project stages transferred to private partner	Legal owner of project assets	Risk redistribution	Project financing	Payment for provided services
DBFOM, DBFO, DCMF	Design, Build/Construct, Finance, Operate, Maintain/Manage	Public partner	Private partner: Construction risk, Operational risk, Demand risk, Political risk, Financial risk, Reputational risk Public partner: Asset ownership, Reputational risk	Private partner	Government or Service user
BOT, BOOT	Build, Own, Operate, Transfer	Private partner until the end of contract, public partner thereafter	Private partner: Construction risk, Operational risk, Demand risk, Political risk, Asset ownership, Financial risk (sometimes and only partially), Reputational risk Public partner: Financial risk, Reputational risk	Public and Private partner, for BOT sometimes Public only	Government or Service user
BTO	Build, Transfer, Operate	Private partner until the end of construction, public partner thereafter	Private partner: Construction risk, Operational risk, Demand risk, Political risk, Financial risk (sometimes and only partially), Reputational risk Public partner: Asset ownership, Financial risk, Reputational risk	Public and Private partner, sometimes Public only	Government or Service user
ROT	Rehabilitate, Operate, Transfer	Private partner until the end of contract, public partner thereafter	Private partner: Reconstruction risk, Operational risk, Demand risk, Political risk, Asset ownership, Financial risk (sometimes and only partially), Reputational risk Public partner: Financial risk, Reputational risk	Public and Private partner, sometimes Public only	Government or Service user
Private Finance Initiative	Design, Build, Finance, Maintain, may include Operations, often not providing services directly to users	Public partner	Private partner: Construction risk, Political risk, Financial risk, Operational risk (sometimes), Demand risk (sometimes) Public partner: Operational risk (sometimes), Demand risk (sometimes), Asset ownership, Reputational risk	Private partner	Government
Operations and Maintenance	Operate, Maintain	Public partner	Private partner: Operational risk, Demand risk, Political risk, Financial risk, Reputational risk Public partner: Asset ownership, Reputational risk	Private partner	Government

Source: Authors, adapted from World Bank Group (2017) and Wang et al. (2018).

Different PPP models are separated into different groups based on their common features. The names of the models, such as BOT, represent the abbreviation of the project stages that are transferred to the private partner: i.e., BOT – Build, Own, Transfer. Eight different common project stages have been identified (World Bank Group, 2017). These are further presented in Table 2. It is worth mentioning that different project stages do not have to be the exclusive responsibility of one of the partners, but can be shared.

Table 2: Project stages

Project stage	
Design	The private partner is responsible for developing the solution proposed by the project into a construction-ready design specification.
Build/Construct	The private partner constructs the infrastructure asset and installs the necessary equipment.
Rehabilitate	Similar to construct, however the asset in question already exists and the private partner is tasked with reconstruction, renovation etc.
Finance	Private partner is required to finance the necessary capital expenditure entirely or in part.
Operate	Providing the services intended by the project to the government or service users (end consumer).
Maintain/Manage	Represents the responsibility of the private party to maintaining the project asset over the life of the contract.
Own	The private partner holds the legal ownership of the asset and connecting economic rights.
Transfer	The private partner transfers the legal ownership to the public partner.

Source: Authors, adapted from World Bank Group (2017)

PPPS AND RISK ALLOCATION

PPPs are immensely complex arrangements, and most of their risks stem from this complexity (Grimsey & Lewis, 2002). It is, therefore, paramount that comprehensive governance and management is well planned and executed (Keers & Van Fenema, 2018), while keeping in mind that the redistribution of

risk is the essence of the PPP model (Zakharina et al., 2020). At the beginning of the PPP project, it is common practice to create a risk register that recognizes all the risks related to the project and its stakeholders (World Bank Group, 2017). Different components of projects, such as their stages, regulations, and project types (and so on), affect the allocation of risks (Wang et al., 2018). It is understood that the risk distribution and, thus, the types of risks, shift between partners throughout the project depending on the project stage (Grimsey & Lewis, 2002; Rybnicek et al., 2020). While the project stages determine risks, specific projects will bear different types of risks. Therefore, it is important to assess the risks for different projects separately, in detail, and define the contracts that adequately disperse the risks among the partners before the public tender (Grimsey & Lewis, 2002). Contracts have been identified as the most important determinant of risk distribution, as they legally determine the allocation of risk responsibilities and, ideally, also list the possible risk factors that can be expected (Rybnicek et al., 2020). Rybnicek et al. (2020) show that poorly planned PPPs have the risk of moral hazard, adverse selection and governmental opportunism that can sprout from contract ambiguities, information asymmetry and insufficient distribution of roles and rights.

Certain risks are common in different types of PPPs and are usually grouped by the particular project phases (World Bank Group, 2017). Different research papers list the most common risks, some of which are technical, construction, operational, revenue, financial, force majeure, regulatory, political, environmental, default, and governance risks (Grimsey & Lewis, 2002; Mazher et al., 2022) a subject that has received scant attention in the extant literature. The research is based on a comprehensive literature review, expert interviews and a questionnaire survey. Mean score ranking and factor analysis were employed to rank and group the identified measures, respectively. Tests were performed to determine the respondents' agreement and establish the reliability and validity of the survey instrument. Analysis results indicate that all identified measures are important, are distributed over the entire project's life cycle and exhibit a multi-organizational focus. The most significant measures focus on PPP-specific artifacts and procurement activities that are vital for ERM. Factor analysis established six critical underlying dimensions for the ERM of PPP projects. The extracted factors generally acknowledge the need for expert public- and private-sector project stakeholders with mature organizational structures, business processes and relevant experience to successfully handle and deliver PPP projects. Furthermore, a comprehensive PPP policy and sound legal and regulatory frameworks are essential for supporting the ERM of PPP projects. The findings will enable a better understanding of factors that influence the quality and outcomes of risk man-

agement efforts and promote sustainable infrastructure development via PPPs, where the success of a project strongly relies on positively managing a project's risks in the economic and the social domains.”,”container-title”:”Sustainability”,”DOI”:”10.3390/su142114149”,”ISSN”:”2071-1050”,”issue”:”21”,”journalAbbreviation”:”Sustainability”,”language”:”en”,”license”:”https://creativecommons.org/licenses/by/4.0/”,”page”:”14149”,”source”:”DOI.org (Crossref. PPP risks can also stem from the relationships among the partners (Keers & Van Fenema, 2018). Nizkorodov (2021, p.3) synthesises project-specific and general risks in PPPs from a number of authors specifically discussing different types of risks, and we will borrow it (verbatim) as the central concept reference. Its core advantage for this analysis is that it corresponds to Table 1, adapted from the World Bank Group (2017).

Table 3: Synthesis of types of risk in PPP projects

Risk Type	Description
Design and Permitting	Inadequate investigation of geotechnical constraints, delays in the design process, and ambiguities and inconsistencies in design that require design changes.
Construction	Cost overruns and delays due to faulty construction techniques and implementation challenges.
Environmental	Adverse environmental impacts and hazards such as droughts, floods, landslides, fires, and earthquakes.
Revenue	Events or conditions that negatively impact future revenue such as changes in demand, taxation, and the prices of inputs.
Financial	The possibility of losing money on an investment due to price and costs increases, financiers withdrawing, changes in interest rates, or poorly designed financial structures.
Political	Changes in legislation and/or political interference. This is a key concern to the private sector, particularly in developing countries where political stability is low.
Public Perception/ Reputational	Arises when the government's public accountability is in question. The extent to which the media is supportive of a PPP project and public perceptions influence the reputational risk to the public partner. Reputational risk also impacts the private partner's perception of credibility.
Public	Refers to any potential loss, damage, threat, or any other hazard in a public space. It is the government's duty to ensure that the facilities are constructed in accordance with legislation.
Force Majeure	Unforeseen risks that are outside of the control of both parties such as war, calamities, and acts of God.

Source: Nizkorodov, 2021, p. 3

Different partners are better suited for the management of specific risks. Bing et al. (2005) suggest that the public sector should shoulder the macro-level risks, such as political, public or reputational, or risks that are exogenous to the project, while the financial or revenue risks should be borne by the private partner. Similarly, Shen et al. (2006) argue that in a successful partnership, the acquisition of site (permissions) and legislative risks should be allocated to the public partner, while those related to other project stages, such as design, construction or operation risks, are better managed by the private partner. However, the authors also state that some risks, such as market risk, force majeure and financial risk, should be shared among the partners. Wang et al. (2018) found that the literature review agrees with the idea of risk being allocated depending on the function of each partner, particularly the construction and demand (revenue) risks. They have also found that the literature on PPPs generally agrees that the more project stages are transferred to the partner, the higher the risk for the partner. For example, Grimsey and Lewis (2002) and Cheung and Chan (2011) find that if the private partners are the providers of financing, it carries significant risks as they rely on the project cashflows from the services and facilities (often provided by the public partner) to compensate for the higher risk. Thus, even though project stages may be separated, the risks are continuous and interactive throughout the project lifecycle, and the partners depend on each other to mitigate each other's actions and ensure the project's sustained use. There is considerable uncertainty, and agreeing on the liability and risk distribution between PPP partners is key to ensuring they are well-oriented to securing continuing public benefit and value (Hrytsenko et al., 2021).

RELATIONSHIP BETWEEN RISK ALLOCATION AND SUSTAINABILITY

PPP projects are generally large, costly, long-term, and involve multiple stakeholders, which makes them complex and thus challenging for ensuring sustainability. Often focused on infrastructure building, they are relevant to countries' social, economic and environmental performance (Ma et al., 2017). While the role of the public sector in promoting the sustainability of PPP projects is obvious and impactful, the private partner is often focused on the financial and revenue risks, in the framework of cost-effectiveness and value-for-money concerns (Ma et al., 2020). Following this, research on PPP projects' risk management largely focuses on exploring financial, resource and revenue risks, downplaying the relevance of sustainability risks (Akomea-Frimpong et al., 2024; Bai et al., 2017; Ma et al., 2020; Yu et al., 2018). A typical example is user fees. An

essential sustainability-related objective for the public partner is to keep them low and affordable to its entire population, whilst the private partner might aim to increase the fees in order to get a return on investment (Yu et al., 2018). The more the public sector partner is financially involved in the project, the greater resources are invested in project sustainability and regulatory compliance, and vice versa (Ma et al., 2020). The design and operational risks, often delegated to the private partner, ensure the continuous quality of the public service and ideally reflect their social responsibility, but its unsatisfactory delivery is a risk which reflects reputationally or politically on the public partner (Ma et al., 2017).

These and similar concerns demonstrate the intertwinement of the risk distribution and sustainability of PPP projects. Inefficient risk distribution hampers the sustainability performance of PPP projects (Liu et al., 2024). As mentioned, risk is an element which is present throughout the PPP projects' lifecycles, as the design and build phases impact the quality of operations, whose results directly influence the target achievements of the projects. These, in turn, are recognized by the public, i.e. the end-users of the products or services thus delivered, which carries social and environmental risks, not only in terms of sustainable delivery, but also of potential hazards (Du et al., 2018).

Bai et al. (2017) and Hrysenko et al. (2021) directly analyse the sustainability risks within the frameworks of PPP projects. Their application of this concept aims to capture the PPP projects' financial, social and environmental performance during their lifecycle. Recognizing their centrality, the risks they analyse are not much different from the typical risk types of PPPs (see Table 2), as their frameworks incorporate economic, project and organizational, and political risks, adding cultural, social and environmental risks. They find in empirical research that the environmental and project/organizational risks are the most relevant sustainability risk factors. Nizkodorov (2021) further investigates the environmental and social impacts of PPP partnerships, and their relationship to the distribution of risks between public and private partners. Based on a qualitative study of 10 PPPs in the U.S., she finds that construction, financial, operational and maintenance risks are best left to the private sector so that the public partner can invest resources to monitor the quality of service and ensure public welfare. However, while this is true in theory, the risks are best allocated to the partner who is best able to manage them, and in practice, such contractual agreements are the results of negotiation processes between the partners. These negotiations are affected by the partners' levels of commitment, prior experiences, the bargaining power of the potential partners and so on, eschewing the risk allocation into sometimes environmentally and socially inefficient contractual agreements.

Empirical research based on a content analysis of PPP contracts in the analysis of risk allocation is somewhat scarce (Castelblanco et al., 2021; Castelblanco & Guevara, 2022; Nguyen et al., 2018; Tallaki & Bracci, 2021; Zhang et al., 2016)2021; Zhang et al., 2016. Most research uses interviews, survey methods, and literature reviews to examine these issues (Zhang et al., 2016). In addition, literature reviews show that sustainability remains an underrepresented area of inquiry in the field of PPP research (Castelblanco et al., 2021; Castelblanco & Guevara, 2022; Wang et al., 2018). An analysis of risk distribution in such contracts in relation to sustainability has so far only been performed by Marques and Berg (2011) and Castelblanco et al. (2020) despite being an important topic for scholars and practitioners, the existing literature does not provide sufficient evidence on how managing risks in solicited (SP. PPP contracts clearly specify the project stages and assets which are allocated to the different partners, and accordingly, the risks they carry have strong impacts on the management of projects in their orientation to economic returns, as well as environmental and social concerns. Marques and Berg (2011), however, use a sample of only two PPP contracts, one of which is a concession arrangement and the other a mixed ownership company, and neither of these cases is comparable to our study sample. In the case of Castelblanco et al. (2020), the building of road infrastructures in Chile largely coalesced around the DBFOM contract models, noting that, for example, in China, the US, the Netherlands and the UK, the PPP models for road construction are different (also Nguyen et al., 2018). The implication of road infrastructure PPP projects in Chile, a country more comparable to Croatia, in choosing these models was that by transferring design, construction, operation and maintenance to the private partner, the public partner would take over asset ownership and absorb demand, thus ensuring long-term use and sustainability. In the following sections, we elaborate on the PPP contract models used in Croatia and the implications of their risk distribution towards sustainability. First, we describe the methods by which the contracts were analysed, then we present the findings, and discuss what the findings might imply regarding the sustainability of PPP projects in Croatia.

METHODS

In this paper, the authors use contract data obtained from the registry of PPP projects of the Ministry of Economy. On their website, the Registry of Contracts is made available to the public (Ministry of Economy, Entrepreneurship and Crafts, n.d.). A total of 17 projects are registered, which vary in value,

scope, duration and other parameters. The authors analysed their contract summaries as these are legal agreements which guide the projects. While not the most common, contract analysis has been used in PPP research since contracts represent governance mechanisms and decision-making processes agreed upon by PPP partners (Castelblanco et al., 2020; Chou & Pramudawardhani, 2015; Jiang et al., 2019; Shrestha et al., 2019, Hodge, 2004).

This research data was analysed using qualitative content analysis (Elo & Kyngäs, 2008; Kolbe & Burnett, 1991), similar to Castelblanco et al. (2020) and Marques and Berg (2011). Firstly, we ascertained the models and operational definitions and summarized them in Tables 1 and 3. The contract texts for each project were then interpreted via qualitative analysis, and each project was coded for the industry and sector of the project, the private partner's core business activities, and the project stages transferred to the private partner, with separate inquiries for the ownership of project assets and project financing. The contract durations and values in EUR were also noted. This process ensured reliability and objectivity by ascertaining coding reliability and minimizing researcher bias (Kolbe & Burnett, 1991). Based on this analysis, the models were compared to the standardized model types by the World Bank (Table 1), and each project was classified. We compared this to the risk/responsibility table (Table 3) in the final step, building a project risk matrix. This method allowed us to ascertain the most common models of PPPs used in Croatia and their risk/responsibility allocation models. As Castelblanco et al. (2020) and Nguyen et al. (2018) suggest, this method is very effective for systematically evaluating the content available in such documentation.

FINDINGS

In this section, we perform a comparative analysis of risk allocation schemes in Croatian PPP projects, which are then discussed through their sustainability-related implications using the available knowledge. In order to ascertain the developments connected to the public-private partnerships in Croatia, this paper analyses the details of all the projects published in the PPP Registry available on the website of the Ministry of the Economy. Croatia has seventeen PPP projects that have been contracted, amounting to the total investment value of EUR 339.85 million. The projects were differentiated according to the Industry, Private Partner Core Activities, Duration, Transferred Responsibilities, Asset Ownership, Project Value and the Model Type. Table 4 gives an overview of the Partnerships.

Table 4: Croatian PPP projects analysis

Project	Industry of the project	Private partner core business activities	Contract duration	Project stages transferred to private partner	Legal owner of project assets	Project financing	Project value in euro	Model type
Zagreb Airport	Transport - aviation	Airport management	30 years	Design, Build, Finance, Operate, Maintain	Private partner until the end of contract, public partner thereafter	Private partner	188,572,566.20	DBFOM with different asset ownership
Varaždin Sports Arena	Sport	Construction, design and construction supervision, construction of civil engineering facilities, real estate management	24 years	Design, Build, Finance, Operate, Maintain	Private partner until the end of contract, public partner thereafter	Private partner	32,515,068.02	DBFOM with different asset ownership
Osljeck Bus Station	Transport - road	Passenger transport and tourism	30 years	Design, Build, Finance, Operate, Maintain	Private partner until the end of contract, public partner thereafter	Private partner	15,926,737.01	DBFOM with different asset ownership
Koprivnica High School	Education	Construction, design and construction supervision Real estate management	25 years	Design, Build, Finance, Operate, Maintain	Private partner until the end of contract, public partner thereafter	Private partner	9,233,099.21	DBFOM with different asset ownership
Split Sports Arena	Sport	Real estate management, provision of services in nautical, rural, health, congress, sports, hunting and other forms of tourism, provision of other tourist services	30 years	Design, Build, Finance, Operate, Maintain	Private partner until the end of contract, public partner thereafter	Private partner	66,892,295.44	DBFOM with different asset ownership
Public lighting – Novi Vinodolski	Public service	Energy generation, transmission and distribution Real estate management	12 years	Design, Reconstruct, Finance, Operate, Maintain	?	Private partner	556,679.01	DRFOM
Public lighting – Kostrena Municipality	Public service	Energy generation, transmission and distribution Real estate management	12 years	Design, Reconstruct, Finance, Operate, Maintain	?	Private partner	243,131.33	DRFOM
Public lighting – Kraljevica	Public service	Energy services, management of energy facilities, conducting energy audits of public lighting, research and development in energy, energy generation, transmission and distribution	16 years	Design, Reconstruct, Finance, Operate, Maintain	?	Private partner	552,126.88	DRFOM
Reconstruction of several different schools in Varaždin County	Education	Different private partners with similar core business activities Construction, design and construction supervision on the school	25 or 30 years depending on the school	Design, Build/Reconstruct, Finance, Operate, Maintain	Private partner until the end of contract, public partner thereafter	Private partner	31,576,881.76	DBFOM with different asset ownership
Varaždin County Building	Public service	Construction, design and construction supervision Real estate management	20 years	Design, Reconstruct, Finance, Operate, Maintain	Private partner until the end of contract, public partner thereafter	Private partner	1,191,450.39	DRFOM with different asset ownership

Source: Authors

The projects span the following four different industries: transport, sport, education and public service. The most represented industry with nine different projects is the education industry. Eight of those projects are related to the reconstruction and renovation of schools and the construction of school gyms in Varaždin County, while the remaining one is related to the construction of a new high school and related facilities in the city of Koprivnica. Following the education industry is the public service industry, with four projects. These include the renovation of the Varaždin County Building in the city of Varaždin, and reconstruction and maintenance of public lighting infrastructure in two cities and one municipality. The other two industries share the last place, each with two projects. The sports industry, with sports arenas in Varaždin and Split, and the transportation industry, with the Zagreb Airport and Osijek Bus Station projects. Although the education industry is most represented, the transport industry projects are the most valuable in terms of investments. Those two projects represent roughly two-thirds of the total PPP value in Croatia, with Zagreb Airport pulling most of the weight.

Interestingly, most of the public partners in the partnership, upon being chosen as a partner by the public sector partner, have created something akin to special purpose vehicles to act as a private partner in the relationship. This is recognized in the literature as a regular practice (World Bank et al., 2017). Upon closer examination, it is not necessarily surprising that all the core business activities of the private partners correspond closely with their role in the partnership. For instance, the company IMC d.o.o. from Rijeka has won two partnership contracts from two different public partners, the City of Novi Vinodolski and Kostrena Municipality. Both projects are related to the public lightning activities. According to the Registry however, the public partner for Novi Vinodolski project is IMC NOVI d.o.o. and for Kostrena is IMC Kostrena d.o.o. The most represented core activity of the private partner is real estate management, which is aligned with the majority of tasks of private partners in these Croatian PPPs. Some private partners have also listed construction, design and supervision as their core activities. Depending on the project, some are even more specialized, i.e., the private partner for the Zagreb Airport has airport management listed as its core activity in the Croatian Court Registry.

In relation to the duration of contracts, it has been observed that projects related to any sort of construction and real estate management and building maintenance tend to involve longer time spans, mostly between 25-30 years. Those are more complex projects which are simultaneously of a higher investment value. The reason for the projects' longevity might be due to the need for

profitability, as the longer the private partner maintains the constructed asset and is paid by the beneficiary of its services, be it the public partner, the citizens or some third party, the greater the return is on its investment. However, this hypothesis was induced based on the limited data available and should be examined more closely in future research. Similarly, the lower value projects, which do not include the construction of a new building and its maintenance, are of shorter duration, mostly around 12 years.

One of the most important aspects of PPPs in terms of sustainability is the transfer of responsibilities to the private partner, and all Croatian PPPs have the same design in this regard. They represent a form of DB(R)FOM model type, meaning that the private partner is assigned the responsibilities of design, construction or reconstruction, financing, operation and maintenance of the project during the life cycle. The projects in Croatia are initially completely financed by private partners, who are then compensated by the public partner during the project's operational life cycle. This is done through payments for the services, which are mostly set ahead in contracts. The public partner is responsible for ensuring revenue throughout the contract duration. Interestingly, the model used for the PPPs in Croatia stands out in one significant element. Assets constructed or reconstructed by the private partner remain in its ownership during the whole duration of the contract, and it is only at the end of the contract transferred to the public partner. This deviates from the DBFOM models as seen in the World Bank's PPP reference guide. Such change means that almost all of the most important risks are transferred from the public to the private partner.

It was discovered in the research that the Croatian PPPs use standardized contracts in combination with the same model for all the projects regardless of the industry or project specifics. In reference to the model type DBFOM in Table 1 and Table 3 (the project risks), private partners in Croatia are exposed to design and construction risks, environmental risks, revenue risks, political risks, and financial risks. Compared to the model type DBFOM in Table 1, the reputational risks remain vague as they are clearly within the domain of the private partner until the end of the contract, but are then transferred to the public partner. In terms of sustainability, it questions who bears the sustainability risk. This remains the same regardless of the project duration, and whether the service is in education or transport. A closer analysis, however, shows that most projects involve constructing or reconstructing materials, buildings, or other facilities. Such projects have very long life spans. On the other hand, for example, public lighting in three of the projects is relevant to the clean energy transition, but has the shortest contract durations of only 12-16 years.

DISCUSSION

One of the goals of this research was to conduct a comparative analysis of the different models applied to the PPPs in Croatia. However, the research showed that only the DBFOM model is used, and the only difference is whether the assets (i.e., building) are to be constructed or if they already exist and require only reconstruction or renovation. From the perspective of different industries and projects, this approach is impractical. While the DBFOM model makes sense for projects such as Zagreb Airport, where a specialized private partner has the ownership of the assets and manages the daily operation of the airport, the model lacks practicality in cases such as the renovation of schools. Under the DBFOM model, the private partners should design, renovate, finance, operate and manage the school in question. However, this is impractical. The private partner, according to the model, should operate a school which is part of the Croatian public education system. The school employees should thus be employed by the private partner, but they are, in fact, paid by the state. As the schools are in practice governed by the Croatian public education system, the private partner is not operating the schools, but only maintaining them. In this case, a much more suitable model would, for example, be the Private Finance Initiative, under which the private partner should only design, construct, finance and manage the asset, while the public partner operates it. The universality of the single PPP model in Croatia shows the fundamental misunderstanding of a successful approach to such relationships.

Because all of the Croatian PPP projects have the same PPP contract model, it could be argued that the risks may not be adequately dispersed among the partners, and that the possible risks might not have been exhausted beforehand, as would be suggested by best practices (Grimsey and Lewis, 2002; World Bank et al., 2017). Regarding sustainability, since financial risks, discussed earlier as possibly the most relevant to good sustainability configurations (Shen et al., 2006; Grimsey and Lewis, 2002; Cheung and Chan, 2011; Ma et al., 2017), are borne by the private partner, they may be less invested in project sustainability, especially since their revenue is only guaranteed during the project duration. The more the public partner is financially involved, the greater resources will be invested in sustainable goals (Ma et al., 2020), not least because the quality and accessibility of future public services will reflect poorly on the reputation of the public partner (Ma et al., 2017). Possibly, as is the case with Chilean road infrastructure PPP projects (Castelblanco et al., 2020), which also follow the DBFOM model, it is expected that the public partner, by taking over asset ownership and absorbing demand, would ensure long-term use. Nonetheless,

there are no mentions of the environmental or social dimensions of sustainability after contract expiration, and it is upon the public partner, as typical in any other public projects, to ensure these procedures.

Recently, Mašović et al. (2024) published a review of the literature on public-private partnerships in Croatia. As these authors note, the general agreement is that current regulatory frameworks do not support alternative PPP models. Domestic authors point out that financial and legal frameworks in Croatia had not been fully developed to support adequate risk distributions at the time of their signing (Marenjak & Kušljic, 2009; Juričić, 2008; Šimović & Rogić Lugarić, 2012; Devčić et al., 2014; Juričić & Marenjak, 2016; Jelinčić et al., 2017; Tijanić et al., 2019). Solid and adequate financial and legal frameworks are necessary to ensure long-term project sustainability. Some authors in Croatia have discussed the issues of risk that the PPP project partners in Croatia are facing, such as the political risk (Bogovac et al., 2019; Jelinčić et al., 2017; Abdou, 2024) and financial risk to partners (Persoli, 2010; Devčić et al., 2014; Juričić & Marenjak, 2016). However, the question of sustainability is rarely addressed, with the exception of Devčić et al. (2014), and it has been suggested that specific criteria for evaluating PPP projects in Croatia should be developed (Abdou, 2024), hopefully also addressing sustainability measures.

The homogeneity of Croatian PPP projects, even though they are heavily reliant on private partners, also has its benefits. Firstly, these projects are made attractive to the private partner because of their clauses of regular and guaranteed remuneration during contract durations. In addition, because the contracts are so similar, partners can rely on previous experiences to engage in new projects, as evidenced by the public lightning and school building PPPs, some of which are even with the same private partner. Nonetheless, standardised contracting cannot address the long-term effects of these PPP projects and their lifecycle impact in general. Decisions which are made during the design and construction phases, herein left to the private partner, may lead to significant sustainability challenges and negatively impact the overall outcomes of PPP projects.

CONCLUSION

This paper provides an overview of the Croatian public-private partnerships and compares them to the conventional models, as well as between each other. Since its independence, only 17 PPPs have been arranged in Croatia. The projects involve four different industries, the most important of which, accord-

ing to the project value, is the transport industry, while the most represented in several projects is the education industry. Private partners operate in the industries of the projects in which they are involved and create SPVs to provide further specialization, as is customary in PPPs. The contract duration varies from project to project, involving significant construction or reconstruction of buildings lasting up to 30 years. All of the partnerships are similar variations of the DBFOM model, however, they have different asset ownerships than the conventional one. The most concerning issues are lack of specialized contract arrangements and unclear sustainability assessments, which makes the Croatian PPP projects risk-prone. It could be hypothesized that this issue could be one of the causes for the lower popularity of PPPs in Croatia, however, this warrants further research.

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IMPACTS OF TOURISM DEVELOPMENT ON LOCAL COMMUNITIES' QUALITY OF LIFE

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There is little doubt that tourism development has a significant impact on the quality of life of local communities. Despite the fact that tourism development should enable a higher quality of life for both hosts and guests, the focus is often on achieving high economic impact at the destination level as the main objective. As a result, the potential of tourism to meet the needs of the local people is not always reached, thus leading to numerous disruptions in the destinations. This study, therefore, discusses the different viewpoints of local communities according to their level of involvement in tourism and dependence on tourism revenues.

The primary research was conducted in the period between July and October 2023 among the residents of Split, Croatia. A total of 538 valid responses were collected and analysed. The aim of the primary research was to gain a deeper understanding of the local population's views on tourism development in Split. It also aimed to investigate how they see their quality of life affected by this development. The respondents' opinions on the main causes of the change in the relationship between tourists and the local population in Split indicate that the significance value of the Chi-square test is $p < 0.05$, suggesting that a statistically significant difference was found in relation to whether or not they receive direct income from tourism. An unclear tourism development strategy emerges as

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one of the main confounding factors for this relationship in the selected destination.

The main conclusions from this study suggest that numerous factors influence tourism development in Split in general and the local community's perception of the quality of this development in particular. Depending on their place of residence in the city and their dependence on tourism revenues, several differences can be identified between the groups of respondents, and their level of satisfaction differs significantly. Although tourism development has a significant economic impact on the local community, overall satisfaction with this development is not fully in line with the positive economic outcomes. The paper presents the tourism policy as an important driver of change at the destination level, with a focus on achieving an overall good quality of life of the local community and balancing the interests of all stakeholders involved in the process.

Keywords: *Tourism development, economic impacts, quality of life, local communities*

JEL classification: *L83, Z32, I31*

INTRODUCTION

With the intense increase in global tourist flows, more attention is being paid to the impact of tourism on local economies and especially on local communities. As Bimonte and D'Agostino (2021: 1510) note, the number of studies on the relationship between the perceived impact of tourism and the subjective well-being of residents is increasing significantly. In general, quality of life is a highly subjective category – while one person may define it in terms of “wealth or life satisfaction, another person may define it in terms of capabilities (e.g. the ability to live a good life in terms of emotional and physical well-being)” (Britannica). Accordingly, “it is important to note that quality of life is a subjective measure of one's well-being” (Berkeley Well-Being Institute).

As the importance of tourism as a global economic force continues to grow, it seems imperative to monitor and manage its impact, especially at the local level. For example, “in 2023, the travel and tourism sector contributed 9.1% to global GDP and created 27 million new jobs, while domestic visitor spending exceeded 2019 levels and international visitor spending increased by 33.1% in 2023 (but still remained below 2019 levels)” (WTTC). Given the size

of this market, it makes sense to measure tourism output not only in terms of its economic potential – the assessment must be based on its overall impact at all levels. For example, the socio-cultural impact of tourism manifests itself in the form of positive long-term changes in a society and is usually expressed in a higher standard of living, the appearance of the community, better quality of public services, restoration of historic buildings and preservation of local culture (Stumpf, Lusticky, Vojtko & Jere Jakulin, 2022: 4).

Positive economic impacts are reflected in local communities and encourage a general willingness to develop tourism. The community's perceived economic responsibility arising from sustainable tourism reinforces the community's belief that tourism activities are aimed at creating better employment opportunities, improving skills, raising living standards, promoting domestic sourcing, and are geared towards supporting local businesses (Mathew & P. M., 2022: 990). "If local people have the opportunity to experience the benefits and be involved in the decision-making process, this could contribute to the successful long-term development of the destination" (Moghavvemi, Woosnam, Hamzah & Hassani, 2021: 268). It could be argued that positive tourism development can have a significant impact on the residents' happiness levels. "The sources of happiness have evolved from materialistic notions (money buys happiness) to the satisfaction of desires to the fulfilment of one's ability to do what one values in life (Aristotle's *eudaimonia*)" (Rivera et al., 2016: 6). Furthermore, Wang, Dai, Ou and Ma (2021: 2) claim that the overall happiness of tourism destination residents includes three dimensions: material well-being, emotional well-being and self-development.

However, there is another potential outcome of tourism development in destinations that is related to its negative impacts and causes numerous disruptions worldwide. Wai Lai and Hithchcock (2017: 452) argue that it is possible that tourism development in communities can lead to unexpected nuisances and disruptions that eventually lead residents to question the value of the industry. Apart from questioning the value of the industry, such a situation tends to have a negative impact on the quality of life of residents, the satisfaction of visitors and the conditions for future tourism development in the destinations. Under these conditions, it is necessary to identify the proportion of the population that is directly involved in tourism activities and the proportion of those who do not benefit directly from tourism development. Therefore, the focus of this study is to discuss the different viewpoints of local communities regarding their involvement in tourism and their dependence on tourism revenues. Based on the results of the primary research conducted in Split (Croatia), the aim is to determine how tourism development affects the residents' quality of life, and

to what extent the place of residence in the city influences the locals' perception of the future development of the city.

THEORETICAL BACKGROUND

The local community's support for tourism development depends on the extent to which it is dependent on tourism revenue. Residents tend to support tourism growth if they are financially dependent on the industry and enjoy its benefits and revenues (Moghavvemi, Jam & Khan, 2024: 6). According to the study conducted by Munanura and Kline (2023), it can be concluded that residents' perceived impacts of tourism are an important factor in their support for tourism. Similarly, a study by Çelik and Rasoolimanesh (2023) emphasised that "residents' negative and positive attitudes towards tourism have direct effects on cost-benefit attitudes and indirect effects on support for tourism". It can be assumed that residents' dependence on tourism has a direct impact on their perceived quality of life, as well as the costs and benefits of such development. These circumstances must be taken into account when discussing the potential impacts of tourism in communities and when defining sustainable development policies. Therefore, "it cannot be denied that increased tourism brings economic prosperity to the area, but residents suffer a variety of negative consequences" (Gautam, 2023: 877).

The concept of sustainability is at the heart of tourism-related development strategies. "According to the capitals approach, developed within the framework of neoclassical economic theory, the condition for sustainable development is that each generation leaves the next generation a stock of productive capacity in the form of capital assets and technology that enables sustainable well-being per capita at a level no less than that of the present generation" (Dwyer, 2013a: 2131). A development strategy that focuses on benefits for present and future generations relies heavily on the concept of resource conservation, with community well-being at the centre of all activities. A study by Fakfare and Wattanacharoensil (2021: 1134) emphasises that community well-being is influenced by the positive perception of economic impact, cultural impact and positive attitudes of the residents who see the community market as a good driver of community development.

As emphasised earlier, quality of life is a highly subjective category and should be analysed accordingly. Thus, cognitive evaluations refer to the extent to which individuals perceive that events affect their subjective well-being, while affective evaluations involve the assessment of the moods and emotions

evoked by the experience of an event. A person's subjective well-being thus includes reactions and moods in combination with cognitive evaluations of satisfaction or fulfilment (Chen, Cottam & Lin, 2020: 31). On the objective side, "quality of life is associated with living conditions that depend on several factors, including work, income, personal and family life, social support, stress and crises, health status, and relationship with the environment" (Rivera et al., 2016: 7). While these elements can be calculated and measured, subjective well-being is quite difficult to determine as it "comprises three elements: life evaluation, experiential values (moment to moment emotions) and *eudaimonia* (meaning and purpose in life)" (Dwyer, 2024: 212).

The issue of resident participation is crucial in determining the quality of life. Therefore, it is important to determine the factors that trigger community participation. Godovykh, Ridderstaat and Fyall (2023: 140) claim that novelty can contribute to the well-being of residents who constantly meet new visitors and have new experiences. Another perspective relates to the unstable conditions, as tourist numbers are volatile, leading to a perceived loss of control by the residents. Such a situation is not necessarily dependent on the temporal component, as residents feel discomfort as soon as they perceive the loss of control. Gössling, McCabe and Chen (2020: 5) claim that residents may be unwilling to move because they feel connected to the place, have a sense of belonging or cannot move for personal, situational reasons, e.g. family ties. A study conducted by Hu, Li, Liu and Chen (2024) emphasises that future research on residents' quality of life in the context of tourism development should focus on building a conceptual framework that combines tourists' and residents' perspectives on the quality of life, combines objective and subjective scales to improve generalizability, and examines the quality of life/well-being from the eudaimonic tradition in order to understand the broader context of quality of life.

The issue of well-being is closely linked to power within and outside the community. The more power residents have over their own lives and living conditions, the more willing they will be to encourage the development of tourism activities in their local economy. However, there is a debate about what the concept of development implies and how it should be evaluated. The concept of development often has a strong ideological underpinning with conservative, liberal and radical traditions that have led to differing views on the causes of development challenges and their likely solutions (Wall, 1997: 35). Therefore, it is of utmost importance to provide local communities with all the necessary information about what tourism development is expected to bring to the local economy, and to shift the perceived benefits from the purely economic component to the all-encompassing benefits for all residents.

Table 1: Empowerment of local communities

Type	Signs of empowerment
Economic	Tourism brings long-term financial benefits to a destination community. The money is distributed throughout the community. There are tangible improvements in local services and infrastructure.
Psychological	Growing confidence in the community prompts members to seek further education and training opportunities. Access to jobs and cash leads to a rise in the status of residents who normally have a low status, such as women and youth.
Social	Tourism maintains or improves the balance of the local community. Community cohesion is improved as individuals and families work together to build a successful industry.
Political	The agencies that initiate or implement tourism projects seek the opinions of community groups and individual community members and offer them the opportunity to be represented in decision-making bodies.

Source: Jamal & Dredge, 2015: 198

The process of managing tourism development faces far greater challenges if the expected benefits are not achieved or if the impacts of tourism development led to a deterioration of living conditions. As Moghavvemi et al. (2021: 273) claim, dissatisfaction of local residents due to the negative impacts of tourism indirectly affects the entire industry, as the level of overall satisfaction of local residents can determine the success or failure of tourism. Such a situation is often related to the increase in tourist flows and exceeding of carrying capacity. Thus, when the impact of tourism on the carrying capacity of a region increases, locals tend to adopt a negative attitude towards tourism (Akdu & Ödemiş, 2018: 35). However, some studies emphasise that residents' behaviour and decisions cannot be easily predicted. For example, "residents may not be willing to sacrifice part of the economic gain in exchange for a lower cost to the society such as pollution" (Cheng, So & Nang Fong, 2022: 283). However, this only means that it is crucial to understand the community's attachment to tourism development and to increase knowledge about the carrying capacity and acceptable changes to the environment as a result of tourism development. According to Park, Lee and Lee (2017: 163), recognising the importance of the community to tourism development must take into account a variety of aspects such as residents' quality of life, community attachment and satisfaction.

Dwyer (2024) highlights several features of the strategic action agenda of degrowth researchers – beyond GDP, reduced production, reduced consumption, reduced inequalities in income and wealth, reduced working hours, redefined business models, relocalization and institutional reform. These measures

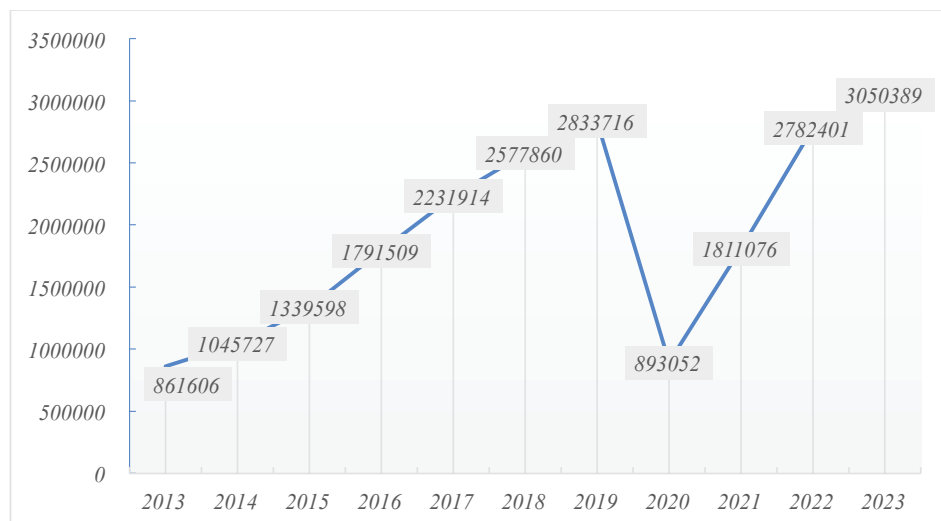
have the potential to mitigate the negative effects of tourism development in the destinations. Another study by Dwyer (2023b: 2400) emphasises that while the Beyond GDP approach was not developed specifically for tourism, it offers comprehensive and realistic ways to measure the sustainability and well-being of destinations, as well as policy recommendations that can be used to manage tourism development in a way that best maintains the well-being of residents in the long term. Such an understanding of the concept of well-being could increase awareness of the role of well-being in communities, and contribute to the overall satisfaction of residents. Understanding the complex and interdisciplinary nature of tourism should lead to improved conditions for its development. Balancing the interests, costs and benefits of tourism stakeholders is at the heart of this issue, with local communities playing the central role in this process.

METHODOLOGY

Based on the theoretical background, previous research and relevant indicators (size of the destination, overnight stays, seasonality, stage of the destination life cycle...), primary research was conducted in the city of Split. Split is the second largest Croatian city and the largest one on the Croatian coast with 160,000 inhabitants (CBS, 2021). It dates back to the time of the Roman Emperor Diocletian, who built his palace near the Roman city of Salona. Diocletian's Palace and the historic centre of Split were inscribed on the UNESCO World Heritage List in 1979. These resources, together with the favourable climatic conditions and geographical position, enabled Split to develop its tourist product and position itself on the international tourism market. According to the Master Plan for Tourism Development (2017-2027) of Split-Dalmatia County (2017), the portfolio of primary tourism products consists of cultural heritage (cultural tourism), yachting (nautical tourism) and gastronomy tourism (excellent gourmet and wine experiences), in addition to the sun and sea, hiking tourism (Marjan hill, forest, jogging trails, mountaineering and cycling), event tourism (theatre festivals, exhibitions, concerts) and party tourism (clubs and bars or festivals, such as the Ultra Europe Festival which is attended by 150,000 people every year).

When it comes to the physical economic impact of tourism, the most analysed indicator is the number of overnight stays. As indicated in Figure 1, Split registered over 3 million overnight stays in 2023 (surpassing pre-pandemic figures). In the ten-year period under review, the number of overnight stays increased 3.5-fold (to over 2 million).

Figure 1: Overnight stays in Split (2013-2023)



Source: Tourist Board of Split, 2024

This significant increase led to an increase in the number of accommodation facilities, restaurants, bars, stores and other tourist service providers. The positive effects on destination level can also be reflected in the increased income from tourism, employment, taxes (as noted by Stumpf et al., 2022: 4). However, since most tourists in Split are motivated by the sun and sea, Split (like the whole of Croatia) is faced with high seasonality. From June to September, Split records 70% of all its overnight stays (Tourist Board of Split, 2024). More than 2 million overnight stays in a 4-month period bring numerous challenges. The increase in overnight stays, especially in the city centre, together with seasonality, leads to invasive changes brought on by mass tourism. This has led to locals having to “fight for the city” in order to maintain a dignified and adequate living environment (especially in the historic centre). These are still spontaneous attempts, primarily in response to external factors, but could become a serious problem in the coming years if the number of tourists continues to increase. For all these reasons, the aim of the primary research is to gain a deeper understanding of the local population’s perceptions of the development of tourism in Split. It also aims to investigate how they see their quality of life affected by this development.

For the purpose of conducting the primary research, a highly structured questionnaire was created (based on the research of Mathieson and Wall in 1982, and partly based on Fan, Liu and Qiu, 2018) and distributed online via Google Form to the residents of Split, in the period between July and October 2023. In order to reach the planned number of 500 respondents, a convenience sampling method was used. Although the main advantage of this sampling method is that the desired number of respondents can be reached relatively quickly and easily, it is important to keep in mind the fact that there is a risk that such a sample does not fully represent the population, and therefore caution is required when drawing conclusions from the research results. The link to the online survey was posted in social media groups whose members live in Split. A total of 538 valid responses were collected and analysed in SPSS using descriptive statistics and Pearson’s chi-square test.

RESULTS AND DISCUSSION

The demographic characteristics of the respondents are presented in Table 2.

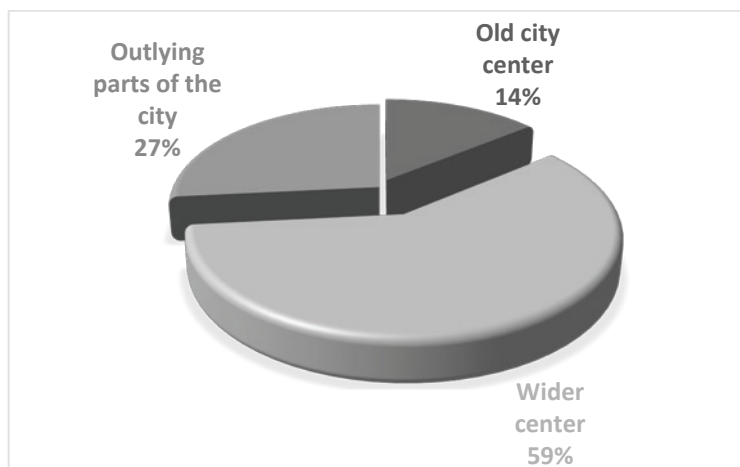
Table 2: Demographic characteristic of respondents

		N	%			N	%
Age	< 29	72	13.4	The highest completed level of education	Primary school	1	0.2
	30 - 55	386	71.7		High school	156	29.0
	> 56	80	14.9		College education	312	58.0
	Total	538	100.0		Postgraduate study	69	12.8
					In total	538	100.0

Source: Primary research

Furthermore, almost 75% of respondents have lived in Split since birth, 16% have lived in Split for more than 20 years, 6% for more than 10 years, while only 3% have lived there for less than 10 years. The distribution of respondents according to the part of Split they live in is shown in Figure 2.

Figure 2: Respondents' place of residence



Source: Primary research

An important characteristic of the respondents is their direct involvement in the provision of tourism services. Accordingly, 72.3% of the respondents receive direct income from tourism, while 27.7% have no income from tourism. The quality of life of the local population is strongly influenced by the socio-cultural impacts of tourism. Table 3 indicates how the local population perceives the socio-cultural impacts of tourism development in Split.

Table 3: Perception of tourism impacts

Statement	$\bar{x}$	Sd
I am satisfied with the achieved level of tourism development in Split.	2.25	1.32
Tourism brings numerous benefits to the inhabitants of the city of Split.	3.07	1.38
Tourism has significantly improved the quality of local infrastructure.	2.19	1.31
Tourism has a positive effect on strengthening the local identity of Split.	2.26	1.33
Tourism strengthens the local population's pride in Split's heritage.	2.43	1.39
The economic benefits of tourism outweigh the social costs.	2.72	1.40

Source: Primary research

Respondents rated their perception of the intended impacts on a Likert scale ranging from 1 to 5 (1 - I strongly disagree; 5 - I strongly agree). The highest value of the arithmetic mean was recorded for the statement "Tourism brings numerous benefits to the inhabitants of the city of Split", where the

arithmetic mean of the respondents' answers is 3.07, while the standard deviation is 1.38. The lowest value of the arithmetic mean of the respondents' answers was recorded for the statement "Tourism has significantly improved the quality of local infrastructure", where the arithmetic mean of the respondents' answers is 2.19, while the standard deviation is 1.31.

In accordance with the theoretical framework and the results of previous studies, a Chi-square test was conducted to determine whether there are significant differences in the perception of the impact of tourism depending on two characteristics of the respondents - generating direct income from tourism and part of Split which they live in. The results are shown in Table 4.

Table 4: Differences in perceptions of tourism impacts

		Do you generate direct income from tourism?	Which part of Split do you live in?
I am satisfied with the achieved level of tourism development in Split.	Chi-square	16.763	9.758
	df	4	4
	Sig.	.002*	.045*
Tourism brings numerous benefits to the inhabitants of the city of Split.	Chi-square	44.481	12.276
	df	4	4
	Sig.	.000*	.015*
Tourism has significantly improved the quality of local infrastructure.	Chi-square	42.497	7.440
	df	4	4
	Sig.	.000*	.114
Tourism has a positive effect on strengthening the local identity of Split.	Chi-square	30.798	10.544
	df	4	4
	Sig.	.000*	.032*
Tourism strengthens the local population's pride in Split's heritage.	Chi-square	32.371	10.965
	df	4	4
	Sig.	.000*	.027*
The economic benefits of tourism outweigh the social costs.	Chi-square	35.423	9.118
	df	4	4
	Sig.	.000*	.058
Tourists endanger the quality of our daily lives.	Chi-square	31.538	25.313
	df	4	4
	Sig.	.000*	.000*

Source: Primary research

There is a statistically significant difference in the perceptions of all impacts depending on the income from tourism. These differences are particularly visible in the following impacts:

- benefits for the inhabitants of the city of Split (almost 70% of the respondents who generate direct income from tourism agree with the statement, while the group of respondents without direct income from tourism accounts for less than 40%),
- improved quality of local infrastructure,
- positive effect on strengthening the local identity of Split and strengthening the pride of the local population in Split's heritage (about 40% of the respondents, who generate direct income from tourism agree with the statement, while the group of respondents without direct income from tourism accounts for about 20%),
- the economic benefits of tourism outweigh the social costs (half of the respondents who generate direct income from tourism agree with the statement, while the group of respondents without direct income from tourism accounts for about 25%).

There are slightly smaller differences in satisfaction with the level of tourism development achieved, where the majority of respondents in both groups are not satisfied, and in the threat to the quality of daily life, where the majority of respondents also believe that tourists have a negative impact on the quality of life. As expected, although both groups of respondents are aware of the negative consequences, those who derive a direct income from tourism are more aware of the benefits that tourism brings, which is also a consequence of their own direct benefit.

When it comes to differences depending on the part of Split which they live in (the old city centre or the wider centre and the outlying parts of the city), a significant difference was observed in five out of seven impacts examined. Almost half of the respondents who live in the wider and the outlying parts of the city agree that tourism brings numerous benefits to the city residents, while less than 25% of the respondents who live in the old city centre agree with this statement. Furthermore, the majority of the respondents believe that tourism does not have a positive impact on strengthening the local identity of Split, but the share is significantly higher among the respondents who live in the old city centre. Significant differences are visible concerning the opinion on the quality of everyday life, where as many as 85% of the residents of the old city centre consider that it is endangered by the presence of tourists, while less than 70% of the respondents in the other group agree with the subject statement. This result is completely expected given the fact that the residents of the old city

centre encounter the tourists and crowds brought about by tourism during the season every day, while those who live in the wider centre and the outlying parts of the city feel this, but to a lesser extent. Impacts without a significant difference refer to the improvement of local infrastructure and economic benefits which outweigh the social costs.

When asked about the main cause of the change in the relationship between tourists and locals in Split, 40% of the respondents cited the unclear tourism development strategy as the main cause, 30% consider the change in the tourist structure to be the main cause, while 14% of respondents claim that the main cause is the change in Split's image as a tourist destination. A smaller number of respondents believe that the main cause of the change is the change in the tourism product, lack of interest from the public sector or other reasons, while only 3% of the respondents claim that relations have not changed.

Finally, a Chi-square test was conducted to determine whether there are significant differences in the perception of the main cause of change in the relationship between the local population and tourists in terms of the respondents who achieve direct income from tourism and those who do not. Overall, the research results indicate that Split residents believe that tourism brings them numerous benefits (Table 3), suggesting that they are aware that it has a positive impact on their quality of life. At the same time, the arithmetic mean indicates that respondents believe that the economic benefits of tourism outweigh the social costs, which is consistent with the findings of Cheng, So & Nang Fong (2022). Both assumptions tested (source of income and place of residence) have a strong influence on the residents' perceptions of tourism development in Split. These results suggest that residents have a strong awareness of the impact of tourism development, but when it comes to the issue of long-term quality of life, significant efforts need to be made to create stimulating conditions and limits to growth in order to ensure a sustainable environment for the destination and its residents. In addition, this study highlighted that tourism development is more supported by those residents who receive a direct income from this activity, which is consistent with the findings of the study conducted by Fan et al. (2019), who claim that hosts are more supportive of tourism development because their personal well-being improves with the development of the tourism industry. Another important issue that arises from this study is the issue of overtourism. As Gössling et al. (2020) point out, overtourism leads to a situation where residents feel that they have no internal control over tourism or tourism activities, and psychologically, a decrease in satisfaction with the place promotes anti-tourism sentiments. Since the research findings suggest that residents of the old city centre in Split expect their

quality of life to deteriorate, policy makers need to consider the fact that the current tourism development could have negative long-term consequences.

Based on the research findings, several recommendations for decision-makers can be highlighted so as to mitigate the issues arising from the dissatisfaction of a significant proportion of residents, and to enable successful future tourism development:

- *Relieve the existing attractions in the old city centre* and develop new attractions outside the old city centre. Both the temporal and spatial dispersion of visitors would be beneficial, although the implementation of this measure would depend on visitor management tools;
- *Regulation of the real estate market* by controlling the rental platforms (limiting the number of tourist apartments), which is currently being introduced at the national level;
- *Improving public transportation* and creating pedestrian zones in the most visited parts of the destination, while introducing a greater number of public transport lines connecting the tourist sites with the peripheral areas of the city;
- *Preserving the local culture and identity* by encouraging local entrepreneurship (e.g. craftsmen and artisans) or organizing events aimed at the local population and not just tourists;
- *Educating tourists* by emphasizing clear rules of conduct and promoting responsible tourism behaviour (this has already been introduced through the “Respect for the City” program, but would benefit from stronger monitoring and sanctioning if necessary);
- *Communication and cooperation with the local population*, i.e. involving the local community in the decision-making processes.

CONCLUSION

Although this study provides valuable insights into the perceptions of Split residents regarding the impact of tourism development on their quality of life, it has its limitations as the research was conducted at the very end of the 2023 tourist season, when residents’ tolerance towards tourism and tourists tends to be somewhat lower due to the high volume of tourists in a short period of time. In addition, it would be highly advisable to conduct the survey in a specific time period so that the time series allow for more reliable conclusions to be drawn and changes within the community to be captured. Building on these findings, future studies should include additional elements of subjective well-

being in order to obtain a comprehensive overview of the impact of tourism development in Split. Future studies should consider the findings of the study conducted by Godovykh et al. (2023), which distinguishes between long-term and short-term impacts of tourism development on well-being, and should incorporate these conclusions into the research framework. The study by Gemar, Soler and Moniche (2023) and the recent study by Li and Sun (2025), which examine the relationship between tourism development and the well-being of residents in the leading destinations, should also be considered in order to gain insights into how to improve the positive impacts of tourism development on local communities.

Nevertheless, the results of this study imply that the residents of Split have a high awareness of the impacts of tourism development in this destination. The impact on the quality of life is viewed positively by the respondents, although there are some indications that they also perceive economic benefits as being able to surpass potentially negative social impacts. As this destination is highly dependent on tourism, there is a statistically significant difference between the perceptions of residents who derive an income from tourism and those who do not. Considering that excessive tourism activity can be the cause of disruption within a destination, it is important to take the residents' perceptions into account and adapt the development strategies accordingly in order to achieve a comprehensive sustainable development policy.

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ENVIRONMENTAL DEGRADATION EFFECTS OF URBANISATION AND TOURISM IN THE EU

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Within a broader goal of carbon neutrality, the EU countries are making significant efforts to decouple urbanisation and tourism growth from environmental damage. Urbanisation, accompanied by over-tourism pressure in many European countries, contributes to environmental degradation through energy-demanding production and consumption, energy-intensive support industries, accommodation, waste production, transportation, and other pollution-inducing activities. In the context of environmental degradation, urbanisation and tourism often overlap, intensifying their effects on land, water and air quality. This paper focuses on the impact of urbanisation pressure on environmental degradation while taking into account the effects of international tourist arrivals. The main aim of this paper is to evaluate the impact of urbanisation on environmental degradation, using the tourism-extended Environmental Kuznets Curve across 27 EU countries for the period 2014–2024. Employing a panel fixed effects model, in a tourism-extended Environmental Kuznets Curve style, we investigate a nonlinear relationship between tourism intensity and environmental degradation, while controlling for economic development, urbanisation and energy consumption. The main findings indicate a statistically significant non-linear effect of tourism and a negative impact of urbanisation rates on environmental degradation in

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the EU, while the environmental effect of economic development renders statistically insignificant. These results suggest that European countries may have reached the limits of urbanisation, minimizing further increases in air pollution due to increases in urbanisation rates. Additionally, European cities fiercely fight carbon dioxide emissions and prioritise carbon neutrality by implementing stronger regulations and focusing on smart, energy-efficient development, greater sustainability awareness, green initiatives, and promoting sustainable tourism. However, despite the efforts, balancing economic benefits stemming from urbanisation and tourism with environmental protection remains a significant challenge in the EU. Contributing to the generally inconclusive empirical literature on the tourism-extended Environmental Kuznets Curve, this paper points out the importance of regulations and the active role of supra-national governments in mitigating environmental degradation and ensuring sustainable and responsible tourism.

Keywords: *Urbanisation, tourism, carbon dioxide emissions, European cities, panel data*

JEL classification: *O18, O44, O52, Z3, R11, C33*

INTRODUCTION

In the recent decades, as part of the combat against the ongoing increase of global warming, the interaction between economic growth, urbanisation, tourism development and environmental degradation has been intensely investigated. At the onset of the investigation, during the early 1990s, research was concentrated mainly around the relationship between economic development and environmental degradation. Within that context, Grossman and Krueger (1995:370) defined the so-called Environmental Kuznets Curve (EKC) based on the hypothesis that an “increase in GDP may be associated with worsening environmental conditions in very poor countries” while “air and water quality appear to benefit from economic growth once some critical level of income has been reached”, all the while finding evidence of an inverted-U shape relationship between income levels and several environmental pollutants. Since that seminal article, numerous empirical tests of the EKC hypothesis have been implemented allowing for diverse functional relationships between economic development and environmental degradation, while extending and controlling for various factors such as energy consumption, urbanization and, in the

recent literature – tourism development. The tourism-extended Environmental Kuznets Curve (T-EKC) integrates the role of tourism into the traditional EKC framework – it incorporates an inverted-U shape association between tourism and environmental degradation, acknowledging that tourism, just like economic development, can have both positive and negative environmental impacts, depending on the context and the attained level of economic and tourism development.

Within the context of the environmental degradation-tourism relationship, this study focuses primarily on assessing the influence of urbanisation and tourism developments on human-induced greenhouse gas emissions, as the main cause of global warming and climate change, among the EU countries in the past ten years. While tourism is considered one of the major contributors to national economies through foreign currency inflows, employment generation, and infrastructure improvement (Paramati et al., 2017; Ehigiamusoe, 2020), it may have an adverse effect on the environmental quality. Tourism-related activities play an important role in the increase of the greenhouse gas emissions, accompanied by other negative economic and social consequences of (over)tourism that many tourist destinations in Europe and other parts of the world nowadays face. On the other hand, sustainable environmentally-friendly tourism practices might have a positive environmental impact. Our choice to concentrate on the European countries is motivated by the fact that Europe has been very popular among international tourists in the recent decades, as they account for roughly 50% of the global international tourist arrivals (Lee and Brahmašreene, 2013; European Commission, 2019), with four European countries; namely, France, Spain, Italy and Germany, ranking among the top ten holiday destinations in the world (The Times, 2024). The tourism industry is a pivotal sector of the European industry, contributing significantly to its growth as an essential source of revenue and employment (Lee and Brahmašreene, 2013). At the same time, greenhouse gas emission levels have been rising throughout the EU, calling for the adequate policy responses in order to prioritise and tackle the environmental issues through, among others, green technologies and sustainable tourism development.

The structure of the paper is as follows. The EKC literature is discussed and reviewed in Section 2. Section 3 focuses on the T-EKC literature, while in section 4 we discuss the environmental effects of urbanisation. Section 5 includes the discussion and presentation of our data set, empirical specification and estimation technique. The results are presented and discussed in section 6. The final section concludes the paper.

THE ENVIRONMENTAL KUZNETS CURVE

Based on the idea of an inverted-U shape relationship between economic development and environmental degradation, the Environmental Kuznets Curve (EKC) hypothesis emerged as a central theoretical framework for understanding the environmental impact of economic development. In the comprehensive literature review of the EKC hypothesis, Leal and Marques (2022) conclude that there is a variety of research approaches in terms of modelling and estimation techniques, indicators for dependent and independent variables, as well as a diversity of control variables and inconclusiveness of results. As pointed by Anwar et al. (2022) there is no uniform agreement on “the existence, shape, and turning points of the EKC among researchers”.

In order to demonstrate the diversity and vagueness of the results in the EKC empirical literature, in the following text we will briefly outline the relevant empirical studies across different global contexts and regions. For instance, Yasin et al. (2020) found an inverted-U relationship between economic growth and environmental degradation across developed and developing countries over the period 1996–2016. Focusing on emerging Eastern European and Central Asian countries during the period 1990–2014, Koilo (2019) also confirmed the EKC hypothesis.

In a panel of 14 countries over the period 2002–2018, Khezri et al. (2024) found evidence of a positive linear relationship between GDP per capita and environmental degradation, while the squared relationship between the two is much smaller in size and statistically insignificant.

Before verifying the EKC hypothesis, Azam et al. (2024) first classified 182 countries into four income groups, according to the attained level of development. Using the fully modified ordinary least squares estimator, they confirmed the EKC hypothesis for 84 countries, while for the remaining 98 countries, they found that the association between economic development and environmental degradation is actually a U-shaped curve. Likewise, instead of the hypothesised EKC-type curve, a U-shaped relationship between economic development and environmental degradation was found for the US (Wan and Kim, 2024) and for the Baltic countries (Kar, 2022).

Using historical time series data spanning from 1850, Omay et al. (2024) examined the long-term relationship between economic growth and environmental degradation for the United States and the United Kingdom. The findings did not reveal the conventional inverted-U shape EKC, but a cyclical pattern in the economic growth-environment nexus for both countries. Employing advanced econometric techniques, Omay et al. (2024) found multiple regimes, indicating

that the relationship between economic growth and environmental degradation varies over time, with periods of both improvement and deterioration.

Focusing on the Middle East and North African region, Ben Cheikh and Ben Zaied (2021) examined the relationship between CO₂ emissions and income growth. By letting the data endogenously reveal the true underlying processes, they revealed that the relationship between income growth and environmental degradation does not resemble the conventional inverted-U shape. Instead, the dynamics vary across countries, indicating that economic development, without targeted policy interventions, is not sufficient to sustain environmental improvements.

THE TOURISM-EXTENDED ENVIRONMENTAL KUZNETS CURVE

While it has been well documented that human-induced degradation of the environment has a negative impact on tourism development, the environmental consequences of tourism are still under investigation. In theory, the environmental consequences might encompass both positive and negative impacts, depending on the type and level of development of the tourism industry.

The negative environmental effects of tourism might occur due to the fact that tourism is associated with energy-demanding production and consumption, energy-intensive support industries, accommodation, waste production, transportation, and other pollution-inducing activities. On the other hand, as pointed by Bramwell and Lane (1993) and Lee and Brahmasrene (2013), increased tourism might actually reduce the environmental degradation when it respects the “natural capacities” of local destinations and when national and supranational policies promote low-carbon economy and tourism through the implementation of newer and energy-efficient technologies and stricter environmental regulations. In sum, similar to the environmental impact of economic development, the environmental impact of tourism depends on the type and level of development, as well as the governance frameworks, targeted policy interventions and regulations.

Employing panel cointegration techniques and fixed-effects models, Lee and Brahmasrene (2013) found that tourism and economic growth had the opposite effects on CO₂ emissions in the EU countries during the period from 1988 to 2009. The former exerts a negative, while the latter has a positive effect on CO₂ emissions. Their results also revealed a high negative effect of Foreign Direct Investments on CO₂ emissions, suggesting that sustainable tourism practices and financial openness might reduce environmental degradation.

In the same vein, Dogan and Aslan (2017) also focused on EU countries and found a similar negative effect of tourism on CO₂ emissions, implying that the tourism sector is “not a concern for environmental pollution in the sample countries”.

Analysing the environmental consequences of tourism in Eastern and Western EU countries during the 1991–2013 period, Paramati et al. (2017) found opposed effects in the two sets of countries. Namely, the findings indicate that tourism increases CO₂ emissions in Eastern Europe, while in Western Europe, mainly due to more effective sustainable tourism policies, tourism tends to reduce CO₂ emissions.

While investigating the non-linear impacts of tourism on environmental degradation in Africa, Ehigiamusoe (2020) observed the EKC-type non-linear effect of tourism on environmental degradation, suggesting that tourism initially reduces environmental degradation, but further tourism expansion aggravates it due to increased energy use and fossil fuel consumption. These findings call for African countries to implement green transition reform, invest in research and development, and, in general, employ environmentally friendly incentives and policies to reverse the unfavourable environmental impact of economic growth.

In order to account for the differences in the environmental effect of tourism due to economic developmental stages, Mahadevan and Suardi (2024) examined the nonlinear impact of tourism on environmental degradation, measured by CO₂ emissions and ecological footprint, in developed and developing countries during the 1990–2019 period. For developed countries, they found an inverted-U shape association between tourism and environmental degradation, suggesting that environmental degradation initially rises, but eventually declines with further tourism growth. For developing countries, however, the association exhibits a U-shape which implies that initially, environmental degradation declines as tourism develops, but it starts to rise after tourism reaches a certain threshold level. In sum, this study showed that the environmental impact of tourism on environmental quality varies between developed and developing countries.

URBANISATION AND ENVIRONMENTAL DEGRADATION

In recent decades, researchers within the economy-tourism-environmental degradation nexus have also been exploring the effect of urbanisation. Previous studies have shown different results, while various methodologies

have been used suggesting a complex relationship between urbanisation and environmental issues. The general attitude is that the impact of urbanisation varies according to the different stages of development and the influence of corresponding policies (Poumanyong and Kaneko, 2010; Mahadevan and Suardi, 2024).

Using the panel data on 80 countries for the period 1983–2005, Ponce De Leon Barido and Marshall (2014) investigated how national-level CO₂ emissions are affected by urbanisation and found positive impacts in lower income countries, while the results were negative in the higher income countries with strong environmental policies. Liu et al. (2014) assessed the impact of urbanisation on greenhouse gas emissions from a demographic perspective and found that population density dominates over urbanization rate in changing per capita emissions.

Micro-level studies showed that households in dense urban environments generate significantly lower CO₂ emissions (Fremstad et al., 2018), but household size scale effects depend on whether direct or indirect greenhouse gas emissions are explored. Ala-Mantila et al. (2014) investigated the effects of expenditure, urbanity and household size on total, direct and indirect emissions, and found that indirect emissions dominate the direct ones, at all income and urbanity levels. Furthermore, the same authors emphasized the more service-oriented lifestyles in urban areas and consequences of service demand emissions. Satterthwaite (2009) highlights a large increase in per capita greenhouse emissions in high-income nations as a consequence of rapid growth in consumption.

METHODOLOGY

Within the tourism-extended Environmental Kuznets Curve (EKC) approach, we specified an econometric model outlined in (1) and employed panel regression analysis to estimate the environmental effects of economic activities, tourism and urbanisation. In particular, we used annual data for 27 European countries for the time period 2014–2024, and employed a static fixed-effect panel estimator, as per Mahadevan and Suardi (2024). Although the concepts which we explored are dynamic in nature, the time dimension of our sample is relatively small (and smaller than the cross-sectional dimension), hence, we opted for the static econometric approach.

Given that the tourism-extended Environmental Kuznets Curve assumes a nonlinear relationship between tourism and environmental degradation, in

line with Mahadevan and Suardi (2024), we specified the econometric model (1) as follows¹:

$$GGE_{it} = \beta_0 + \beta_1 GDPpc_{it} + \beta_2 TSp_{it} + \beta_3 TSp_{it}^2 + \beta_4 URBPOP_{it} + \beta_5 ENER_{it} + e_{it} \quad (1)$$

where the number of nations is $i = 1, 2, \dots N$; the number of periods is $t = 1, 2, \dots T$; GGE is the greenhouse gas emission; $GDPpc$ indicates real gross domestic product per capita, TSp and TSp^2 are measures of tourist intensity per capita, in level and squared terms, respectively; $URBPOP$ represents the share of urban population, while $ENER$ denotes energy consumption in households per capita. Apart from the standard (economy and tourism) variables, our tourism-extended Environmental Kuznets Curve model additionally controls for urbanisation and energy consumption. The environmental effects of urbanisation were already discussed in the previous section, while the decision to include the energy consumption variable in the econometric model was guided by the relevant empirical literature where the energy consumption variable was found to aggravate carbon emissions (Ehigiamusoe, 2020; Ben Cheikh and Ben Zaied, 2021; Karr, 2022; Khezri et al., 2024; Azam et al., 2024).

Given that the T-EKC literature implies that environmental damage grows with tourism up to a threshold, after which it begins to decline as countries become more capable of addressing environmental issues, we expect the estimated coefficients on TSp variable to be smaller than 0, while the estimated coefficient on TSp^2 is expected to be larger than 0. That would show evidence of an inverted-U shape association between tourism and environmental degradation, as implied by the T-EKC literature. As for the environmental effect of economic development, based on the attained level of development and a country's dedication to balanced and sustainable economic growth, the literature foresees two opposite effects of economic activities on environmental quality; hence, the sign of the estimated coefficient on this variable is *a priori* uncertain. The same applies for the expected sign of the estimated coefficient on urbanisation, given that, intuitively, we might expect a rise in energy consumption due to urbanisation. However, an increase in the urbanization rate,

¹ In order to assess the nonlinear relationship between tourism and environmental degradation, tourism-extended EKC studies incorporate tourism and tourism² alongside GDP as regressors, with environmental degradation as the dependent variable (Mahadevan and Suardi, 2024).

when paired with good urban planning, may actually reduce environmental degradation due to, among other things, economies of scale and efficient use of resources. Given that energy consumption is a crucial determinant of greenhouse gas emissions, *a priori*, *ENER* is expected to exert a positive effect on environmental degradation.

DATA

Table 1 provides more details on the data employed in our research, while Table 2 reports summary statistics. All of the data that we used, with the exception of urban population, were retrieved from the Eurostat database. The urban population data were collected from the World Bank's database World Development Indicator.

Table 1: Variables, definitions and data sources

Variable	Definitions	Source
GGE	Net greenhouse gas emissions , which include “greenhouse gases (CO ₂ , N ₂ O in CO ₂ equivalent, CH ₄ in CO ₂ equivalent, HFC in CO ₂ equivalent, PFC in CO ₂ equivalent, SF ₆ in CO ₂ equivalent, NF ₃ in CO ₂ equivalent)”, in tonnes, per capita	Eurostat
TSpc	Tourism intensity : the number of nights spent at tourist accommodations divided by the resident population	Eurostat
GDPpc	GDP per capita (at market prices)	Eurostat
URBPOP	Urban population as a percentage of total population	World bank - World Development Indicators
ENER	Final energy consumption in households per capita	Eurostat

Source: Authors' own research

Table 2: Summary statistics

Variable	Obs	Mean	Std. dev.	Min	Max
GGE	243	8.259259	3.735604	.1	20.8
TSpc	241	6302.803	4981.934	747.82	23303.54
GDPpc	243	26860.08	17404.12	5470	86690
URBPOP	243	73.39021	12.91208	53.557	98.153
ENER	243	566.1934	181.7117	170	1076

Source: Authors' own research

The dependent variable in our model, environmental degradation, is measured as the net greenhouse gas emissions per capita, in tonnes. Environmental degradation is a complex and multidimensional concept difficult to measure. In the empirical studies, researchers mainly use CO₂ emissions as a proxy of environmental degradation. However, both the CO₂ emissions and greenhouse gas emissions refer only to the atmosphere degradation, while the water and land (as other main constituents of the environment) degradation, remains unaccounted for². Nonetheless, considering that other studies in this field typically use the data on CO₂ emissions or greenhouse gas emissions, as well as data availability, we opted for greenhouse gas emissions as a measure of environmental degradation. Since we used a composite measure of environmental degradation, it should be mentioned that, as pointed by Ben Cheikh and Ben Zaied (2021:6), it is possible that “some pollutants will be phased out due to technological innovations, while further income growth would raise the emissions of other pollutants when the share of renewables is already filled and the returns on innovative activity are diminishing”. For instance, Bhattacharjee and Chowdhury (2024) found a linear and positive effect of GDP on CO₂, and a EKC type of effect (inverted-U shape) on CH₄ and N₂O.

Our main independent variables of interest were the level of economic development, measured as real GDP per capita, tourism intensity and urbanisation. In order to measure the level of tourism activities and the relative importance of tourism for a country, we used an indicator of tourism intensity calculated by dividing the number of nights spent at tourist accommodations

² Alternatively, the human-induced degradation of the environment might be measured by the ecological footprint which is “an accounting tool used to estimate how much land and water area is required to produce all the goods consumed and to assimilate all the wastes generated by a population or economic sector” (Wang and Dong, 2019: 166). As pointed by Mahadevan and Suardi (2024), CO₂ emissions and ecological footprint, however, “measure different environmental impacts”.

by the resident population. Instead of relying on tourism density, we opted for tourism intensity, since it is considered a superior measure for analysing the environmental impact of tourism (Batista e Silva et al., 2018). The share of urban population in total population was used as a proxy for urbanisation rate, while the level of energy consumption was measured as final energy consumption in households per capita.

RESULTS AND DISCUSSION

We estimated the empirical model outlined in (1) using static fixed effects estimator, whose appropriateness in regards to random effect estimator was proved by Hausman test ($p=0.0002$).

The findings of this study, presented in Table 3, lend support to the T-EKC hypothesis, since the found relationship between tourism and environmental degradation takes on a nonlinear, inverted-U shape. Namely, the estimated coefficient on the tourism variable in levels is positive, and the estimated coefficient on the squared tourism variable is negative, while both prove to be statistically significant. This reflects the idea that initially tourism leads to increased environmental degradation, due to energy-demanding production and consumption, energy-intensive support industries, accommodation, waste production, transportation, and other pollution-inducing activities. After the turning point, further tourism development reduces environmental degradation, as economies transition to sustainable tourism practices, cleaner technologies, improved regulations, and higher environmental awareness. Similar to our findings, an inverted-U shape relationship between tourism and environmental degradation was also found in the study conducted by Ehigiamusoe (2020) for a panel of heterogeneous countries, as well as Mahadevan and Suardi (2024) and Ghosh (2020) for developed countries.

Moreover, our estimated T-EKC model suggests that the environmental effect of economic development is negative, albeit statistically insignificant. Economic growth in the EU is strongly driven by tourism (Lee and Brahmasurene, T. (2013); Paramati et al. (2017); Ehigiamusoe (2020)), hence, it is possible that GDP exerts its effect on environmental degradation through tourism. A negative effect of economic development on environmental degradation in developed countries was also found by Mahadevan and Suardi (2024).

The estimated environmental effect of urbanisation is negative and statistically significant, suggesting that an increase in urbanisation may reduce environmental degradation. This finding is in line with Ponce De Leon Barido

and Marshall (2014), and is not surprising, given that our sample consists of EU countries where cities play a major role in the fight against global climate change through the implementation of low-carbon development strategies, compact urban forms, economies of scale in resource use, centralised utilities, smart transport systems, higher environmental awareness etc.

In line with *a priori* expectations, energy consumption has a statistically significant negative environmental effect, suggesting that an increase in final energy consumption (energy used by end consumers) increases greenhouse gas emissions.

Table 3: Main results

dep: GGE	Coefficient
Cons	37.9314***
	(0.000)
GDPpc	-0.00002
	(0.437)
TSpc	0.00037***
	(0.000)
TS²pc	-9.51e-09***
	(0.005)
URBPOP	-0.4810***
	(0.000)
ENER	0.0078***
	(0.000)

Notes: FE is used. Numbers reported in parentheses are standard errors, while *, ** and *** denote significance at the 10, 5 and 1 percent, respectively.

Source: Authors' own research

CONCLUSION

The relationship between environmental quality, tourism, economic growth, and urbanisation is complex and multidimensional. The environmental impacts of economic development, tourism intensity and urbanisation depend on the context, the attained level of development, and a country's commitment to undertake green transition towards sustainable development. While tourism contributes significantly to economic growth, it can have adverse effects on environmental quality, if not aligned with policies that promote green energy-

efficient technologies and ecotourism with stricter environmental regulations. As Lee and Chen (2021) point out, robust governance frameworks are essential for sustainable tourism.

Despite the differences in methods used, regressors employed, and the country-specific dynamics, the existing empirical literature, ours included, suggests that economic development, tourism intensity and urbanisation do not have forceful detrimental effects on environmental quality in developed countries. Instead, these phenomena contribute to a reduction of environmental degradation. Unfortunately, the opposite environmental effects seem to operate in developing countries. These differences in the environmental impacts in developed and developing countries highlight the fundamental role of governance, globalization, and region-specific and targeted policies in addressing the environmental issues effectively and appropriately.

Another important implication of our study is the importance of the urban dimension in the global fight against global warming and environmental degradation. Our results suggest that European countries may have reached the limits of urbanisation, minimizing further increases in air pollution due to increases in urbanisation rates. Cities are home to more than 70% people in the EU³ and undoubtedly contribute to greenhouse gas emissions. However, European cities compactly concentrate people and economic activities, which benefits environmental quality through economies of scale and energy efficiency. More importantly, EU empowers cities to prioritise carbon neutrality by implementing stronger regulations that encourage sustainable practices. European cities nowadays choose smart, energy-efficient development, invest in sustainability awareness and green initiatives, while reducing over-tourism and promoting sustainable tourism practices. However, despite the efforts, balancing economic benefits stemming from urbanisation and tourism with environmental protection remains a significant challenge in the EU.

Future research in the economic growth-tourism-environment nexus should focus on the implementation of more sophisticated econometric techniques, particularly those which allow for the spatial dependence and heterogeneity, given that the environmental effects cross national borders and are spatially dependent. In addition, in order to develop appropriate context- and region-specific strategies for sustainable tourism development, further research should concentrate on developing countries which are facing increasing urbanisation rates and suffering significant environmental losses.

³ In our sample, mean urbanisation rate equals to 73.4%.

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THE PARADOX OF FOREIGN INVESTMENTS: IS CAPITAL THE KEY OR A BRAKE ON PRODUCTIVITY?

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Productivity is a fundamental driver of economic growth, reflecting a nation's efficiency in utilising resources to produce goods and services. The countries of Central and Southeastern (SE) Europe have experienced significant economic transformations, with some integrating into the European Union. Understanding the drivers of labour productivity is crucial for achieving sustainable growth and enhancing competitiveness in the global market. However, these countries still face challenges related to low labour productivity, impacting wages, employment, and living standards.

This paper builds on a prior study conducted in Croatia with the aim to analyse the key determinants of labour productivity in Central and SE Europe. It uses panel data from 13 countries from the period between 2000 and 2023, employing a panel data regression model to assess the impact of four independent variables: foreign direct investment (FDI), primary education levels, tertiary education levels, and investment in research and development.

Findings for Croatia indicated that education positively influences labour productivity, while FDI has a negative effect. Expanding this analysis to other countries is expected to provide insight into the similarities and differences of how these factors affect labour productivity, leading to

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a better understanding of regional trends and potential economic growth policies.

This paper contributes to the discourse on labour productivity by providing evidence on the effects of education, innovation, and foreign capital in the region. The conclusions significantly affect the development of policies aiming to enhance productivity and competitiveness across Central and SE European economies.

Keywords: *Labour productivity, foreign direct investment, level of education, research and development*

JEL classification: *E22, E24*

INTRODUCTION

Recent studies have primarily examined the impact of foreign direct investment (FDI) on economic growth, revealing its positive effects on development. The economic theory posits a favourable relationship between economic development and productivity, suggesting that an increase in FDI should correspondingly enhance productivity. However, there is only a limited body of empirical research addressing this correlation. Consequently, this paper focuses on the relationship between FDI and labour productivity while incorporating additional factors such as education level and investment in research and development (R&D), significantly influencing labour productivity growth. Theoretical frameworks indicate that FDI, education, and R&D positively affect a host country's gross domestic product (GDP) growth.

Productivity, defined as output produced per unit of labour, reflects resource utilisation efficiency and is a crucial indicator of a nation's economic health. It demonstrates how effectively resources are transformed into goods and services. Due to distinct economic structures, understanding productivity drivers in Central and SE Europe is essential. These countries have experienced substantial transformations, including a shift from centrally planned to market-oriented economies, EU integration, and increasing global economic interdependence. Despite these advancements, the region struggles with low labour productivity, hampering global competitiveness and the living standards.

FDI is often seen as a means of transferring technology, capital, and management expertise to developing economies, thus potentially enhancing productivity. However, its effects can be unclear. Negative consequences, such as

profit repatriation, the crowding out of local firms, or an overdependence on foreign capital, can obstruct sustained productivity growth.

Another significant factor influencing productivity is education, which is recognised as a critical element in enhancing workforce productivity. Generally, a more educated labour force correlates with increased skills, innovation, and adaptability – vital traits for thriving in a knowledge-based economy. Tertiary education is essential for equipping individuals with the advanced knowledge and expertise required in high-value-added industries, underscoring its importance in the productivity equation.

Alongside education, investment in R&D is essential for fostering innovation, technological advancements, and overall productivity. Countries that allocate substantial resources to R&D

tend to demonstrate higher growth rates as these initiatives stimulate the creation of new technologies and products. This paper examines the degree to which R&D investment drives productivity growth.

Employing a linear regression model, this paper analyses four pivotal variables affecting labour productivity: FDI, primary education, tertiary education, and R&D investment. By utilising data from 2000 to 2023 across 13 Central and SE European countries, the analysis aspires to underline the interactions among these variables, shaping labour productivity over time. The authors assess the contributions of these factors to productivity trends and aim to furnish evidence-based recommendations for policymakers, enhancing the understanding of labour productivity dynamics and emphasising the necessity for integrated policies encompassing FDI, education, and R&D for sustainable economic growth.

This study enriches the existing literature by holistically examining the determinants of labour productivity in Central and SE European countries, focusing keenly on FDI, education, and R&D impacts. Prior research, including studies on Croatia, has acknowledged education as a vital productivity driver while highlighting varying effects of FDI. This analysis broadens the ambit by examining multiple countries to uncover regional trends. Utilising a fixed-effects panel regression model addresses empirical gaps by evaluating whether observed relationships persist across diverse economic contexts and policy landscapes. The findings aim to illuminate the nuanced consequences of FDI, reinforce the critical roles of tertiary education and R&D investment, and provide policymakers with actionable insights to elevate productivity and economic competitiveness, thereby offering a comprehensive perspective on labour productivity dynamics in the region.

LITERATURE REVIEW

PRODUCTIVITY AND FOREIGN DIRECT INVESTMENT

The relationship between FDI and labour productivity is essential for economic growth in developing countries. FDI enhances labour productivity by promoting structural changes and improving overall productivity. Factors such as export orientation, domestic capital, and human capital positively influence this relationship, while government spending and infrastructure development can hinder productivity. Researchers have highlighted that FDI is vital in enhancing labour productivity by introducing new technologies and management practices, contributing to significant economic growth. Economic theory supports a positive correlation between labour productivity and FDI, with various empirical studies confirming this assertion.

Boghean and State (2015) emphasise that the impact of FDI on host economies largely stems from increased labour productivity facilitated by technology transfer, management, and marketing skills. These elements enable long-term technological progress and economic growth. Importantly, they note that the correlation between FDI inflows and hourly productivity is confirmed by 2012 data only for countries with a GDP per capita that exceeds a certain threshold, which is typically found in developed countries with policies established to attract FDI.

The relationship between direct investments and labour productivity was examined by Ng (2007) across 14 countries in Sub-Saharan Africa, where the findings suggest that FDI boosts average labour productivity by introducing new production technologies and implementing efficient management practices. While substantial, not all research supports an unambiguous link between productivity and FDI. For instance, Barbosa and Eiriz (2009) conducted a study in Portugal using the Cobb-Douglas production function model. Their results indicate that foreign firms operating within the same industry as local firms, as well as connections between foreign firms and local suppliers, do not significantly impact productivity. Moreover, they found no productivity spillovers linked to the firms' specific characteristics.

In contrast, Khawar (2003) observed significant positive effects on productivity in firms with foreign ownership in a study based on data from the state of Mexico. Lastly, Derado and Horvatin (2019) empirically investigated the positive effects of total FDI and mergers and acquisitions (M&A) on labour productivity in the home country, noting that greenfield investments yield a positive and statistically significant effect only in the presence of strong innovators.

PRODUCTIVITY AND LEVEL OF EDUCATION

Blundell et al. (1999) analysed how human capital influences economic growth. They assert that output growth depends on the accumulation of human capital and innovation, particularly the education level, which affects labour productivity. The human capital theory states that investing in education enhances skills, increasing individual productivity and income (Magableh et al., 2022). Magableh et al. (2022) highlighted that education fosters economic growth and enhances labour market outcomes in developing and emerging economies.

For instance, a study in Jordan revealed that education significantly boosts labour productivity, with a 1% increase in education correlating to a 1.15% rise in long-term productivity. Chansarn (2010) examined the effect of education on productivity. The regression analysis results indicate a coefficient of 0.208 for mean years of schooling, suggesting that each additional year of schooling results in a 0.208% increase in the annual growth rate of labour productivity. This establishes a clear link between education and productivity, emphasising the importance of educational investments for economic advancement.

PRODUCTIVITY AND INVESTMENTS IN R&D

Attracting FDI has become crucial to many countries' national development strategies. Policymakers often assert that FDI generates significant economic externalities. Consequently, the policy agenda in numerous countries emphasises the need to attract FDI to gain access to capital, new technologies, knowledge, and other vital resources, such as distribution channels. These elements are believed to enhance domestic productivity.

The interplay between productivity and R&D is examined through several avenues, including technological change, the efficiency of R&D investments, and the complementarities among innovations. These areas underscore how R&D fuels productivity growth and highlight the necessity of implementing effective R&D practices across various industrial contexts. Research shows that R&D and information and communication technology (ICT) account for nearly 95% of productivity growth in OECD countries, illustrating a robust connection between technological investment and productivity outcomes (Pieri et al., 2018).

Technological advancement is a primary growth driver in high-tech sectors, particularly in China's national and eastern regions (Chen et al., 2022).

Essentially, the relationship between productivity and R&D is marked by the vital roles of technological progress, efficient R&D investment, and the complementarities between various forms of innovation. Collectively, these factors enhance productivity across diverse industries and underline the significance of strategic R&D management and investment.

Doraszelski and Jaumandreu (2013) demonstrated that the correlation between R&D and productivity entails considerable uncertainty, nonlinearity, and heterogeneity. R&D emerges as a key determinant of the variations in productivity among firms and the trends in firm-level productivity over time.

DATA AND METHODOLOGY

REGRESSION MODEL

The empirical section of this paper investigates the relationship between labour productivity, FDI, education levels, and R&D investments. The main objective is to determine whether labour productivity growth is primarily driven by foreign investment alone, and to analyse how varying levels of educational attainment impact labour productivity. Additionally, the authors explore the connection between R&D investment and labour productivity.

In order to establish the research framework, the authors conducted a literature review which led to the formulation of the following hypotheses:

- H1: Foreign direct investment positively and significantly impacts labour productivity ($\beta_1 > 0$).
- H2: A Primary educated workforce negatively and significantly influences labour productivity ($\beta_2 < 0$).
- H3: A Tertiary educated workforce positively influences labour productivity ($\beta_3 > 0$).
- H4: Investments in research and development positively affect labour productivity ($\beta_4 > 0$).

To test these hypotheses, the authors employed multiple linear regression analysis on panel data collected from Eurostat, ensuring that all information is publicly accessible. The study encompassed 13 EU countries, primarily in Central and SE Europe: Austria, Bulgaria, Croatia, Czechia, Estonia, Greece, Hungary, Latvia, Lithuania, Poland, Romania, Slovenia, and Slovakia, over a period of 24 years – from 2000 to 2023. The multiple linear regression model is defined as follows:

$$\ln LP_{it} = \frac{GDP_{it}}{em_{it}} = \beta_0 + \beta_1 \ln FDI_{it} + \beta_2 \ln PRIM_{it} + \beta_3 \ln TER_{it} + \beta_4 \ln GERD_{it}$$

In this model, LP represents labour productivity in a country i at a time t , GDP denotes gross domestic product for a country i at a time t , em is the number of employees in a country i at a time t , and FDI indicates foreign direct investments in a country i at a time t . $PRIM$, SEC , and TER also refer to the number of individuals with primary, secondary, and tertiary education in a country i at a time t , respectively. $GERD$ represents research and development expenditures for a country i at a time t , while $\beta_{1...4}$ are coefficients to be estimated, and β_0 denotes the constant.

In order to identify the most suitable econometric model for analysing panel data from the 13 countries over the 2000-2023 period, the authors performed several statistical tests aiming to distinguish between pooled ordinary least squares (OLS), random effects (RE), and fixed effects (FE) models. The initial step involved conducting the Breusch and Pagan Lagrange multiplier (LM) test to ascertain whether a random effects model is more appropriate than a pooled OLS model. This test evaluates whether significant differences exist between the entities (countries) included in the study.

The null hypothesis (H_0) posits that the variance between the entities is zero, suggesting no significant difference among them, thus favouring the pooled OLS methodology. Conversely, the alternative hypothesis (H_1) proposes notable variance among the entities, supporting using random effects. The test yielded a p-value of 0.000 (see Figure 1), indicating strong evidence against the null hypothesis and confirming the presence of significant entity-specific variation. Consequently, the pooled OLS model was deemed unsuitable, necessitating a shift in focus to random effects and fixed effects models.

Figure 1: Results of the LM test in STATA

```
. xttest0

Breusch and Pagan Lagrangian multiplier test for random effects

lp[countryID,t] = Xb + u[countryID] + e[countryID,t]

Estimated results:

```

	Var	SD = sqrt(Var)
lp	.3039513	.5513178
e	.0384986	.1962106
u	.0755449	.2748543

```

Test: Var(u) = 0
      chibar2(01) =    795.02
Prob > chibar2 =    0.0000

```

Source: Authors' calculation using STATA

Following the LM test, the Hausman test was performed to determine whether the individual effects are correlated with the explanatory variables. This test can be used to determine whether the model with fixed effects or the model with random effects is more suitable.

Figure 2: Results of the Hausman test in STATA

```
. hausman fe re
```

	Coefficients		(b-B) Difference	sqrt(diag(V_b-V_B)) Std. err.
	(b) fe	(B) re		
fdi	.1735652	.154661	.0189042	.0107172
prim	-.7456377	-.5791671	-.1664707	.0630315
ter	.3075654	.3606577	-.0530923	.0353958
gerd	.161424	.2568914	-.0954675	.0228785

```

      b = Consistent under H0 and Ha; obtained from xtreg.
      B = Inconsistent under Ha, efficient under H0; obtained from xtreg.

Test of H0: Difference in coefficients not systematic

      chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
              =    36.77
Prob > chi2 = 0.0000
(V_b-V_B is not positive definite)

```

Source: Authors' calculation using STATA

The null hypothesis (H_0) of the Hausman test states that there is no correlation between entity-specific effects and explanatory variables, making the random effects model suitable. In contrast, the alternative hypothesis (H_1) asserts that such a correlation exists, favouring the fixed effects model. With a p-value of 0.0000 from the Hausman test (see Figure 2), the authors reject the null hypothesis, indicating a significant correlation. Therefore, the fixed effects model is the preferred method for this analysis, controlling for unobservable, time-invariant characteristics and reducing potential biases in the estimated coefficients.

ENDOGENEITY PROBLEM

In order to test for endogeneity in R&D investments, referred to as *gerd* in this model, the authors conducted an endogeneity test using the instrumental variable (IV) approach. They applied the Hausman-Durbin-Wu test within a regression model that utilised a fixed-effects instrumental variable. In this model, *gerd* is treated as a potentially endogenous variable, with its lagged value as the instrument. This method helps control potential bias using the prior period's *gerd* variable as an instrument. A crucial requirement for a valid instrument is that it must correlate with the endogenous variable (R&D) but not with the model's error term.

In the base model, R&D investment can influence labour productivity, while higher labour productivity may simultaneously lead to increased R&D investment, indicating possible reverse causality. In situations of simultaneity, the estimated coefficients may be biased and inconsistent. Using the lagged value of R&D, the authors ensure that current labour productivity does not affect the instrument. Employing a lagged variable as an instrument is common in panel data analysis as it allows for instrumentalization without needing external data. This approach is beneficial when identifying an external instrument that connects to R&D but not productivity, which proves challenging. The endogeneity test results are illustrated in Figure 3.

The test yielded a p-value of 0.314, suggesting that the authors cannot reject the null hypothesis that the *gerd* variable is exogenous. This indicates that R&D does not demonstrate statistically significant endogeneity in the model presented, implying that fixed-effects regression provides consistent estimates. Consequently, the authors proceed with the fixed-effects model without additional endogeneity corrections. Another potential source of endogeneity in the relationship between FDI and productivity is omitted variable bias. Un-

Figure 3: Endogeneity test of endogenous regressors

```

FIXED EFFECTS ESTIMATION
-----
Number of groups =          13                      Obs per group: min =          19
                                                    avg =          21.6
                                                    max =          23

IV (2SLS) estimation
-----

Estimates efficient for homoskedasticity only
Statistics consistent for homoskedasticity only

Total (centered) SS      = 30.85542991
Total (uncentered) SS   = 30.85542991
Residual SS              = 9.260577874

Number of obs =          281
F( 4, 264) =        154.29
Prob > F      =        0.0000
Centered R2   =        0.6999
Uncentered R2 =        0.6999
Root MSE     =        .1859

+-----+-----+-----+-----+-----+-----+
|      lp      | Coefficient | Std. err. | z   | P>|z| | [95% conf. interval] |
+-----+-----+-----+-----+-----+-----+
| gerd         | .1481       | .0894587  | 1.66 | 0.098 | -.0272359 .3234359 |
| fdi          | .1207244    | .0514694  | 2.35 | 0.019 | .0198462 .2216025 |
| prim        | -.6567238   | .1731662  | -3.79 | 0.000 | -.9961233 -.3173244 |
| ter          | .4082356    | .1139104  | 3.58 | 0.000 | .1849753 .631496 |
+-----+-----+-----+-----+-----+-----+

Underidentification test (Anderson canon. corr. LM statistic):          174.430
                                                                Chi-sq(1) P-val =          0.0000

Weak identification test (Cragg-Donald Wald F statistic):          492.142
Stock-Yogo weak ID test critical values: 10% maximal IV size          16.38
                                           15% maximal IV size          8.96
                                           20% maximal IV size          6.66
                                           25% maximal IV size          5.53

Source: Stock-Yogo (2005). Reproduced by permission.

Sargan statistic (overidentification test of all instruments):          0.000
(equation exactly identified)

-endog- option:
Endogeneity test of endogenous regressors:          1.014
                                                                Chi-sq(1) P-val =          0.3140

Regressors tested:      gerd

Instrumented:            gerd
Included instruments:    fdi prim ter
Excluded instruments:    L.gerd

```

Source: Authors' calculation using STATA

observed factors, such as institutional quality, sectoral composition of FDI, or government policies, may simultaneously affect productivity and FDI inflows.

While the fixed-effects model addresses time-invariant country-specific characteristics, time-varying omitted factors can still lead to biased estimates. In order to address these challenges, future research could use instrumental variable approaches or dynamic panel methods like the Generalized Method of Moments (GMM) to manage endogeneity effectively. However, given the scope of this study and the focus of the endogeneity tests being primarily on R&D investments, the authors rely on the fixed-effects estimation presented. Acknowledging these potential limitations, the authors provide a transparent discussion of the methodological considerations while ensuring the analysis remains centred on the tested variables.

EMPIRICAL RESULTS

The authors applied a fixed-effect regression model to panel data from 13 different states collected over a period of 24 years using the STATA 18 software package. The model's coefficient of determination is 0.7077, indicating that independent variables of the model can explain 70% of the variability in labour productivity within a single unit over time. The coefficient indicating the impact of FDI on labour productivity is positive and statistically significant (p-value = 0.001). The β_1 coefficient value is 0.17 (see Figure 4), which means that a 1% increase in FDI results in an average 0.17% rise in labour productivity, assuming all other variables in the model remain constant. This finding supports the economic theory, as FDI typically brings advanced technology, knowledge transfer, and improved management practices. Therefore, the first hypothesis (H1) can be accepted, recognising that while FDI contributes to productivity growth, its influence is moderate and not the sole or dominant factor in this model.

Conversely, the coefficient representing the impact of individuals with lower levels of education, specifically primary education, on labour productivity is negative and statistically significant (p-value = 0.000). The β_2 coefficient is -0.74 (Figure 4), implying that labour productivity increases by an average of 0.74% for every 1% decrease in the share of the population with primary education, holding other variables constant. This correlation supports the second hypothesis (H2), demonstrating a negative and statistically significant coefficient. In contrast, the coefficient reflecting the influence of individuals with higher education (tertiary education) on labour productivity is positive and statistically significant (p-value = 0.005). The β_3 coefficient value is 0.307 (see Figure

4), suggesting that labour productivity increases by an average of 0.307% for each 1% rise in the population share with tertiary education, assuming other variables remain constant. This finding reinforces the third hypothesis (H3), highlighting the essential role of higher education in enhancing labour productivity. Individuals with higher education typically possess advanced skills and knowledge that foster more efficient and innovative work processes.

Lastly, the coefficient that measures the impact of R&D investment on labour productivity is positive and statistically significant (p-value = 0.028). The β_4 coefficient is 0.16 (see Figure 4), indicating that a 1% increase in R&D investment corresponds to an average 0.16% rise in labour productivity while controlling for other variables in the model. This underscores the significance of R&D investment as a critical driver of innovation and technological advancement that directly enhances labour productivity. Moreover, this highlights the necessity of policies that promote increased resource allocation to R&D activities, as such investments improve efficiency and ensure long-term economic growth and competitiveness.

Figure 4: Results of a regression model with fixed effects

```
. xtreg lp fdi prim ter gerd, fe

Fixed-effects (within) regression      Number of obs   =       290
Group variable: countryID              Number of groups =       13

R-squared:                             Obs per group:
    Within = 0.7077                      min =          19
    Between = 0.0281                     avg  =         22.3
    Overall = 0.2342                      max  =          24

corr(u_i, Xb) = -0.2809                  F(4, 273)       =       165.23
                                         Prob > F         =       0.0000
```

lp	Coefficient	Std. err.	t	P> t	[95% conf. interval]	
fdi	.1735652	.0506905	3.42	0.001	.0737714	.2733591
prim	-.7456377	.167179	-4.46	0.000	-1.074762	-.4165138
ter	.3075654	.1088825	2.82	0.005	.0932093	.5219215
gerd	.161424	.0730027	2.21	0.028	.0177041	.3051439
_cons	3.993362	.8583775	4.65	0.000	2.303481	5.683242
sigma_u	.48707043					
sigma_e	.19621057					
rho	.86037891	(fraction of variance due to u_i)				

F test that all u_i=0: F(12, 273) = 58.00 Prob > F = 0.0000

Source: Authors' calculation using STATA

DISCUSSION

From the results presented in the empirical part of the paper, a conclusion was reached about the factors that influenced labour productivity in the countries of Central and SE Europe in the period from 2000 to 2023. The results confirmed that FDIs have a positive and statistically significant role in the growth and improvement of labour productivity. These observations correspond to the theoretical paradigms confirming that FDI brings advanced technology, experienced management and access to global markets, positively affecting labour productivity. In addition, this result corresponds to the results obtained by Jovanović and Hanzl-Weiss (2022), which showed that FDI has a positive effect on growth in labour productivity, especially in the Energy, Construction, Transportation and Communication, Accommodation and Food, and Real Estate sectors. However, it should be emphasised that the relationship is positive but weak, therefore FDI alone cannot significantly influence labour productivity. Additional factors and incentives are needed to significantly change productivity.

A workforce with basic (primary) education negatively impacts labour productivity, which corresponds to the results obtained by Silva, Moutinho and Gaspar (2024). This group of employees lacks enough knowledge and skills, and they are predominantly employed in workplaces where they do not create products and services with significant added value. This finding underlines the importance of training programs and policies that enable workers to transition to higher levels of education and specialisation.

The positive and statistically significant coefficient supports the hypothesis that a well-educated labour force fosters innovation and economic growth. Various studies (Kampelmann et al., 2018; Kornieieva et al., 2022) indicate that as education levels rise, labour productivity also increases. Higher education equips individuals with advanced skills and abilities, enabling them to use modern technologies and contribute effectively to knowledge-intensive sectors. This educated workforce is predominantly employed in industries that create products and services with significant added value.

Moreover, these individuals typically adapt swiftly to changes in the labour market, embracing new knowledge and technologies that enhance productivity. This adaptability emphasises the need for public policymakers to maximise the proportion of this educated labour force within the overall population by investing in accessible higher education for all. Along with making higher education available, it is crucial to tailor educational programs so as to align with labour market demands and the evolving trends in high technology, ensuring that graduates possess skills relevant to the current industry needs.

Building on this, a study by Szulc-Obłóza and Szczepaniak (2024) found that Denmark demonstrates the most intensive active European intervention. Among Central and SE European countries, Czechia ranks highest, while Romania ranks lowest regarding such intervention. Additionally, Nosova (2022) notes that policies aiming to improve labour productivity employ various strategies to stimulate growth in this area. Empirical evidence from Poland (Wiśniewski, 2022) revealed that start-up incentives and intervention programs significantly impacted labour productivity. Furthermore, positive effects were also observed from supply-oriented labour market policies, such as vocational training and job placement services, which enhance the overall employability of the workforce.

The government supports productivity through different measures. Increased public and private investment in infrastructure leads to higher productivity, drives economic expansion, improves working conditions, and raises wages for skilled workers. These investments result in faster changes at both the firm and industry levels. Additionally, a better business climate is closely linked to human capital development. A skilled workforce is vital for businesses to adopt new, more efficient technologies, while an improved business environment enhances the benefits of investing in education. Companies that gain better access to advanced technologies demand more skilled workers. They are more motivated to pursue growth-oriented activities, thereby boosting both private and societal returns on education.

The variable of investment in R&D is another essential factor of labour productivity. As the authors expected in hypothesis H4, this factor positively affects labour productivity. This realisation underlines the need for sustained investment in R&D and mechanisms to facilitate collaboration between academic institutions, government agencies and the private sector. The positive relationship between R&D spending and labour productivity underlines the transformative potential of innovation and technological progress. Investments in research and development affect the progress of production technology, which shifts the production curve towards higher production volumes but for the same number of inputs. As a result, productivity growth occurs. In addition, regional differences in R&D capacity in Central and SE Europe require targeted support for underperforming areas so as to ensure that the benefits of innovation are evenly distributed. In addition, Kornieieva et al. (2022) showed that an increase in scientific research and development costs correlates with higher labour productivity and growth in R&D spending of enterprises, particularly in high-tech industries, thus positively contributing to productivity.

Empirical results similar to those obtained by the authors in this paper can also be found in research conducted by Popa (2020). The influence of education and FDI is more substantial, but this is expected because the research was conducted in a developed country. In contrast, this research is based on countries with a lower level of development. The results of the conducted calculations and research identified that the most significant impact on increasing labour productivity in the US lies in the degree of innovation of the country, especially the expenses on research and education, with a correlation coefficient of 0.91, followed by competitiveness and multifactorial productivity with a correlation index of 0.83 and 0.81, and FDI with an average correlation of 0.33 (Popa, 2020).

None of the variables researched in the paper, or their influence on labour productivity, have a dominant role. This leads to the conclusion that this is a synergistic effect of the researched variables. Thus, FDI, education, and investment in R&D complement each other, resulting in increased labour productivity. Countries that efficiently and effectively integrate these productivity factors into their public policies are likely to achieve sustainable economic growth and high competitiveness in the global markets.

CONCLUSION

This paper examines the impact of FDI, education and R&D on labour productivity. The study utilises panel data from 13 Central and SE European countries covering the period from 2000 to 2023. The authors employed the STATA software package to analyse the effects of these variables on productivity, and implemented the fixed effects linear regression method. The regression coefficients for all the model variables are statistically significant and align with much of the existing research in this area of economics. The findings provide robust evidence of the significant impacts of FDI, tertiary education and R&D spending on labour productivity, highlighting the detrimental effects of a workforce predominantly comprised of individuals with primary education.

The study reveals that tertiary education has the most substantial impact on labour productivity. A well-educated workforce directly enhances economic performance and creates a multiplier effect that benefits the society and the economy. In order to capitalise on this potential, policymakers should focus on improving the quality and relevance of higher education, ensuring that graduates possess the necessary skills for dynamic labour markets. FDI emerges as

the second most influential variable regarding labour productivity. The positive effect of FDI indicates that attracting these investments is a valuable strategy for enhancing national productivity. However, the relatively low impact coefficient suggests that FDI alone cannot resolve the region's productivity issues. Policymakers must implement complementary measures to bolster human capital, infrastructure, and institutional quality alongside FDI initiatives.

Investment in R&D exhibits a weaker impact on labour productivity, comparable to that of FDI. Promoting investments in R&D within the business sector can foster economic productivity growth, improve integration into global value chains, and boost exports in high-technology fields that generate significant added value. This ultimately increases labour productivity. For transformative investments to restructure the economy, focusing on innovation, patents, and R&D is essential, supported by effective public policy mechanisms. A notable negative influence on labour productivity arises from a low level of education. This factor strongly affects productivity, as individuals with limited education typically occupy jobs that produce simple products and services with low added value. Efforts should be directed towards this workforce segment to promote lifelong learning, thus reducing the percentage of employees with low educational backgrounds.

This study advances the literature on labour productivity by systematically analysing the effects of FDI, education levels, and R&D investments across 13 Central and SE European countries over a period of 24 years. Previous studies focused on Croatia indicated a positive relationship between education and labour productivity, alongside a negative influence of FDI. This study broadens the analysis to a regional context. A fixed-effects panel regression model allows for consideration of country-specific factors, providing a nuanced understanding of these determinants' interactions within different economic frameworks. The results challenge the notion that FDI uniformly boosts productivity, demonstrating that its effects are context-dependent and not consistently significant. Furthermore, this paper contributes to the policy dialogue by emphasising the complementary roles of education and R&D investment in mitigating potential constraints to FDI-driven growth.

Countries can enhance their productivity and competitiveness by integrating FDI, education and R&D investment into a cohesive strategy. Future studies should explore additional variables and their impacts on labour productivity. Sectoral analyses are recommended, as the significance of a highly educated workforce may vary across different sectors. This variability similarly applies to the other examined factors. Although it is necessary to separately analyse the individual sectors, this paper affirms that FDI, education levels and R&D

investments significantly influence labour productivity and the overall productivity of the economy.

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DECOUPLING ECONOMIC GROWTH AND RESOURCE USAGE IN THE NAUTICAL PORTS AND TOURISM INDUSTRY

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The economic growth of nautical ports and tourism highly depends on natural resources such as water, energy and land in terms of availability, quality and ecological preservation. The expansion of nautical tourism industry worldwide is increasing the demand for these resources, leading to a considerable environmental footprint. Nautical ports are complex water-front infrastructures that provide various services, amenities, and utilities. Thus, they consume substantial amounts of natural resources in order to perform their operations. The conventional economic model, “take-make-use-dispose”, cannot sustain and enhance the nautical ports’ business performance without causing adverse environmental impacts. Researchers and practitioners are developing diverse concepts and solutions, such as “decoupling”, in order to balance the economic growth and ecological footprint. Decoupling implies that nautical ports can achieve economic growth while minimizing or reducing the usage of natural resources, such as water or energy, in their operations, while also minimizing the adverse environmental impacts. This paper investigates the relationship between economic performance and the use of natural resources in nautical port operations, including strategies to reduce the sector’s environmental footprint. It analyzes economic performance using diverse financial and market indicators. It also investigates the usage of natural resources as vital items in port operations. The paper uses statistical data on the business performance of nautical ports in Croatia (2009-2022) to decouple eco-

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conomic growth and natural resource consumption. The results show that nautical ports implement diverse sustainability measures such as energy-efficient technologies, water recycling systems, and waste management strategies in order to minimize adverse environmental impacts. Such measures enable nautical ports to effectively decouple their economic performance from using natural resources. Furthermore, the results show that nautical ports achieve a higher increase in financial results relative to resource usage. The paper proposes a decoupling framework that enables tracing and connecting green and sustainable strategies in the nautical sector so as to achieve “resource decoupling” and “impact decoupling”, consequently leading to sustainable development. This study further deepens the understanding of sustainability and the challenges of balanced economic growth relative to environmental issues. It underscores the need to implement decoupling principles and integrate sustainable practices in the nautical ports and recreational boating industry.

Keywords: *Economic growth, business performance, decoupling, environmental footprint, marine resources*

JEL classification: *L83, O44, Q01, Q56, Z32*

INTRODUCTION

Tourism is vital to the global economy and is one of the leading engines of economic development across countries and regions worldwide (Trstenjak et al., 2020; Rasool et al., 2021; World Tourism Organization, 2023; Sampaio et al., 2024). The travel and tourism industry accounts for 10% of the global GDP (data from 2019) and employs 320 million people. Coastal and marine tourism represents at least 50% of total international tourism – a \$9.5 trillion revenue industry that generates every 1 in 11 jobs (World Economic Forum, 2023). It is the largest sector of the EU Blue Economy in terms of GVA (with a share of 29%) and employment (with a share of 54%) (EC, 2024). Many coastal areas have undergone significant economic changes in recent decades, switching from traditional industries (e.g., agriculture, fishing) to tourism and related sectors (Lafranchi et al., 2015). Moreover, tourism is becoming the dominant economic activity and even the only industry in many coastal economies worldwide. For instance, Bogunović and Vitasović (2024) suspect that Istria County (Croatia), a growingly popular coastal destination and one of the most significant tourism densities in the EU, is facing a state of a tourism

monoculture that is threatening its sustainability in the long run. The authors further underscore the problem of a growing imbalance between over-tourism and the carrying capacity of destinations, which leads to a domination of the negative impacts of tourism over its benefits. Tourism overdevelopment is particularly evident in ports and coastal cities, especially in Europe, e.g. in Dubrovnik, where numerous economic, social, cultural and environmental pressures are arising (Abbasian et al., 2020). Island and archipelago destinations that are even more reliant on a tourism monoculture, like the Balearics, are experiencing significant economic declines during major disruptions or crises, such as the pandemic (Blázquez-Salom, 2022). Substantial tourism growth accompanied by continuous urbanization in coastal areas leads to an increased use of marine and coastline resources, jeopardizing the marine environment and creating notable pressures on fragile ecosystems (Lafranchi et al., 2015). The dominant economic model, “take-make-use-dispose”, cannot sustain and improve business performance without causing diverse environmental degradation and, thus, related economic risks (Ellen MacArthur Foundation, 2013). The World Economic Forum (2023) highlights that healthy oceans are the foundation of the coastal and marine tourism industry worldwide, and they are facing significant stressors such as pollution and loss of biodiversity. The environment is crucial to tourism economic activity, and the industry increasingly invests in protecting natural resources and biodiversity conservation (Lafranchi et al., 2015).

The recreational boating industry has significant growth potential and offers various opportunities for diverse stakeholders to invest and do business (ECSIP Consortium, 2015). This attractive segment of the blue economy is increasingly gaining popularity as a relatively new type of vacation spending (ECSIP Consortium, 2015), and is attracting many new markets worldwide. It is estimated that the number of active boaters and water sports participants globally has reached 140 million (Mordor Intelligence, 2024). According to the ECSIP Consortium (2015), the sales volume of the European charter sector is estimated at EUR 6 billion, while the sales volume of EU marinas reaches EUR 4 billion annually. The increased recreational boating industry has led to the construction of numerous waterfront infrastructures and growth in nautical ports (Lafranchi et al., 2015).

Increasing activities in the recreational boating service industry are causing a depletion of natural resources, including air, water and land pollution, congestion, loss of biodiversity, and the like (Marušić, Kovačić & Peronja, 2024), and thus are negatively impacting the environment and social well-being (Trstenjak et al., 2020; Martínez-Vázquez, 2021; Poletan Jugović et al.,

2022; Filimon, 2023; Innovamarina, 2023). Moreover, the growth of the recreational boating service industry is increasing the demand for natural resources and causing a considerable environmental footprint. The recreational boating industry is facing increasing pressure from customers, policymakers, and legislation regarding environmental protection, including requirements for green products and services, and socially responsible behavior (Lück et al., 2007; Trstenjak et al., 2020; Martínez-Vázquez, 2021; The Carbon Trust, 2021; Poletan Jugović et al., 2022). Lafranchi et al. (2015) suggest that tourist demand is mainly oriented towards the most ecologically conserved areas. Therefore, nautical companies build regenerative growth models to reduce their environmental footprint and implement innovative solutions to decouple economic activity from using natural resources. Integrating green and sustainable solutions into nautical ports' business activities requires different considerations, plans, incentives, investments, and implementations in operations and processes.

The paper explores the concept of decoupling economic growth from resource usage and environmental footprint in marinas, including identifying the best practices focused on sustainable development related to resource decoupling and impact decoupling. The goals of the paper include the following: 1) to analyze resource decoupling using a time series of secondary data related to resource usage and economic performances (Croatian Bureau of Statistics, n.d.), and 2) to determine best practices in marinas as key actors in the recreational boating service industry, related to impact decoupling and resource decoupling.

DECOUPLING ECONOMIC ACTIVITY FROM RESOURCE USAGE AND ENVIRONMENTAL FOOTPRINT IN NAUTICAL PORTS AND THE RECREATIONAL BOATING INDUSTRY

THE RECREATIONAL BOATING INDUSTRY

The recreational boating industry is broad and comprises numerous stakeholders and diverse sectors. The leading industry associations differ in the number of recognized recreational boating sectors. For instance, the International Council of Marine Industry Associations (ICOMIA, 2007) distinguishes four sectors (boat builders, engine manufacturers, boat accessory and marine equipment manufacturers, and service providers), while the European Boating Industry (EBI) distinguishes five sectors (boat builders, equipment manufacturers for boats, equipment manufacturers for water sports, infrastructure

builders and operators (marinas), and service providers) (ECSIP Consortium, 2015). The recreational boating industry consists of diverse actors and stakeholders in the recreational boating manufacturing and service industry. The manufacturing recreational boating industry refers to the production, building, and construction of recreational and sporting vessels with no specific restriction on the vessels' hull length. It includes the manufacturing of inflatable boats and rafts, building of sailboats, construction of motorboats, building of recreation-type hovercrafts, and manufacturing of personal watercrafts, canoes, kayaks, rowing boats, and skiffs, including vessels that are commonly known as "super yachts" (ECSIP Consortium, 2015). In literature, recreational boats are also referred to as pleasure boats. The vast majority of boat manufacturers are SMEs (95%), while a small group of major companies dominates the high-end of the boat market. Boat engine manufacturers are predominantly large multinational companies (e.g., Volvo Penta, Mercury, Yamaha, and Honda) and vehicle manufacturers (e.g., Volkswagen, Volvo). Boat manufacturing can be customized (small and local scale) and serial (large scale). Bigger recreational boats are custom-built, while vessels up to 24 meters are mainly built in serial production. The average size of boats has grown in the last ten years due to the demand for bigger boats in the charter market (ECSIP Consortium, 2015).

The recreational boating service industry comprises various activities, with marina and yacht charter activities being the core. Marina and yacht charter activities generate numerous additional or indirect services that constitute the industry value chain. There is no single definition of a marina in literature, considering the range of services and facilities it provides, proprietary rights, different legislation and standards across countries, etc. Marinas can provide basic services and facilities only, or can include diverse additional services and amenities, depending on the type, size, location, and market preferences. Basic marina services refer to berthing and berth-related services and facilities (power and water supply), while additional services may include a broad spectrum of services aimed not only at boats and boaters, but also at other guests and visitors (e.g., dry berthing, boat repair and maintenance, restaurants, accommodation, sport and recreation amenities, etc.). There are over 10,000 marinas in Europe (with over 1 million berths inland and in coastal areas), which are primarily located in Sweden, Finland, the United Kingdom, the Netherlands, Germany, France, Spain, Italy, and Croatia (ICOMIA, 2007; ECSIP Consortium, 2015; The Carbon Trust, 2021). Yacht charter or boat rental is a vital service in recreational boating. It has become increasingly significant over the past few decades, making recreational boating affordable to a broader audience in terms of effort and costs, and facilitating boating activities. Char-

ter can include boat rentals only, or it can also include yacht crew (captain/skipper, hostesses).

The recreational boating industry is experiencing increasing environmental and societal pressures, and is therefore changing and evolving, with significant innovations focusing on more sustainable solutions. For instance, the manufacturing industry is switching to less harmful materials, fuel-savings, and pronounced interest in alternatives to fossil fuel engines, with the rapidly growing electric propulsion (ECSIP Consortium, 2015). Regulations, legislation, technological advancements and innovations in electric mobility are increasing environmental standards and pressuring manufacturers to invest in clean engines. For instance, compared to the rest of the world, due to the European standards aimed at protecting water (drinking water, keeping oceans clean), Europe has become a leader in the electric boating market.

THE CONCEPT OF DECOUPLING

The world's climate and geological environment are subject to increasing pressures (UNEP, 2011), most often caused by irresponsible human behavior at both the organizational and individual levels. Human behavior is the primary driver of air pollution and global warming (Gan, 2024). Population growth and the growth of the population's purchasing power have influenced the growth of demand for products and services, the growth of production, and the growth of demand for limited resources (UNEP, 2011). Resource demand results in increased resource extraction, increasing resource scarcity, price increases and volatility, loss of biodiversity, water pollution, and increasing environmental footprint, which then further leads to adverse impacts on human health and social well-being (UNEP, 2011). Furthermore, the amount of resource consumption per capita per year increased from 4.6 tons in 1905 to 8.5-9.2 tons in 2005 (UNEP, 2011). The average resource consumption per capita in some developing countries was 2 tons in 2015, while the resource consumption per capita in developed countries in 2015 was 30 tons (UNEP, 2011), which confirms the thesis of uneven consumption at the global level. On a global level, production growth is linked to the growth of production resources such as water, energy, and the like (UNEP, 2011).

Scholars and practitioners from different scientific disciplines, trying to find solutions that will enable a balance between industrial growth/consumption, environmental footprint, and social well-being, have developed specific concepts such as degrowth, circular economy, and decoupling. The theoretical

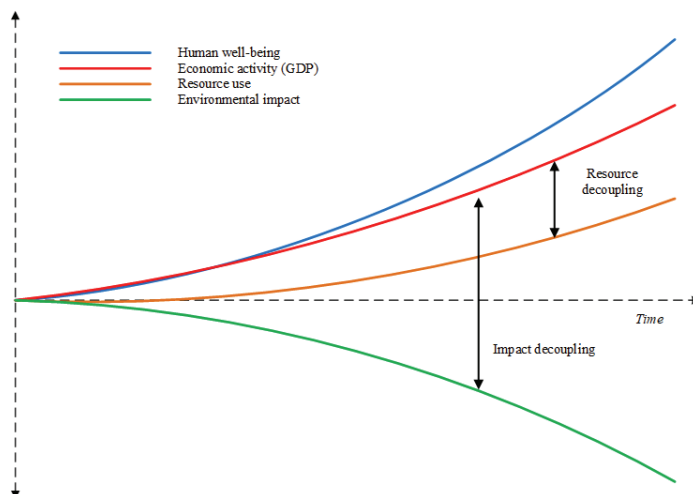
concepts share similar goals, such as further prevention of natural resource destruction, increased social well-being and sustainable development, but offer different recommendations for achieving them. The degrowth concept as a solution advocates reducing the demand and consumption side, and putting a complete stop to economic growth (Cattaneo & Gavalda, 2010; Kallis, Kerschner & Martinez-Alier, 2012). The concept of circular economy (CE) is based on circular solutions and circular economy principles such as reduction, reuse, recycling, and reverse logistics (Uvarova, 2023). Implementing CE into plans, business activities, projects, investments, and stakeholder collaboration reduces resource consumption and environmental impact and extends the product life cycle. Finally, the decoupling concept is based on separating economic activities from the usage of resources, that is, separating economic activities from the environmental footprint (UNEP, 2011). According to the decoupling concept, increased economic activity is not necessarily related to increased resource use and environmental footprint.

Decoupling can be defined as reducing the use of resources such as water or non-renewable energy used for business operations, and delinking economic development from environmental degradation (UNEP, 2011). The aims of decoupling include improving human well-being and social equity, and reducing environmental risks and resource scarcities (UNEP, 2011). Effective decoupling enables the survival of human civilization, serving as a prerequisite for reducing poverty and social inequalities (UNEP, 2011), two of the SDGs (Sustainable Development Goals) adopted by the United Nations in 2015 (UNWTO, 2023). The development of technology and eco-innovation in products, services, and business processes positively affect the achievement of decoupling (UNEP, 2011). According to UNEP's International Resource Panel (UNEP, 2011), there are two aspects of decoupling: resource decoupling and impact decoupling, as presented in Figure 1.

Decoupling makes breaking the link between resource use and economic growth possible. Resource decoupling means maintaining the same economic growth rate while using less resources - land, energy, water, and materials, or reducing the amount of natural resources per unit of economic activity (UNEP, 2011; Hennicke & Khosla, 2014). Resource productivity strengthens resource decoupling. Impact decoupling implies the wise use of resources over their lifetime or the simultaneous increase in economic output and decrease in environmental footprint (UNEP, 2011; Hennicke & Khosla, 2014). The importance of resource decoupling increases with resource scarcity and the level of negative social and environmental impacts that cannot be contained (UNEP, 2011), while the role of impact decoupling increases if resource usage can threaten

human health and ecosystems (UNEP, 2011). Technological development and eco-innovation can prevent environmental and social well-being degradation.

Figure 1: The concept of decoupling



Source: Authors, based on UNEP (2011)

Some markets, such as energy efficiency and sustainable water management, have more potential to decouple economic activities from resource usage and environmental footprint (Hennicke & Khosla, 2014). Very few countries, industries, and markets achieve absolute decoupling - where resources decrease independently of economic activities (UNEP, 2011; Hennicke & Khosla, 2014). On the other hand, numerous industries achieve relative decoupling - a state in which resource use and/or environmental footprint growth is lower than economic growth (UNEP, 2011; Hennicke & Khosla, 2014). Finally, effective decoupling is impossible without the engagement of national governments and politicians and their activities to address threats such as the destruction of natural resources and climate change (Gan, 2024).

Nautical ports use significant marine, coastal and land resources, which makes their sustainable development complex (Poletan Jugović et al., 2022). They provide vital services for boaters and diverse recreational boating industry stakeholders. In addition, recreational boating is often referred to as nautical tourism, and both terms are used interchangeably in the literature (Marušić et al., 2014; Trstenjak et al., 2020; Poletan Jugović et al., 2022; Filimon, 2023; Innovamarina, 2023). Numerous researchers have investigated the environ-

mental and social impacts of nautical tourism (Chen et al., 2017; Hojnik et al., 2020; Trstenjak et al., 2020; Carreño & Lloret, 2021; Martínez-Vázquez et al., 2021; Poletan Jugović et al., 2022), suggesting that the economic growth of the sector causes sustainable environmental pollution in coastal regions (Chen et al., 2017). However, this paper detected a gap in the literature regarding the research on decoupling in nautical tourism. Furthermore, decoupling has been partially explored in the blue economy and its sectors that include nautical tourism, as well as in the tourism industry in general (Cao et al., 2023; Chen et al., 2017; Lanfranchi et al., 2015; Qin & Li, 2021; Xiong et al., 2022; Zha et al., 2021). For instance, Bari (2017) studied the decoupling of socioeconomic benefits from environmental footprint in the blue economy. The author highlighted the impact of environmental protection on long-term prosperity and social well-being. Lanfranchi et al. (2015) calculated a decoupling index in order to analyze the relationship between the economic development of tourism and its ecological-environmental impacts using a decoupling model. They suggested that different regions reach different levels of decoupling, which results from differences in allocating resources, investments, and innovations in tourism. Their findings align with similar research on decoupling in tourism (e.g., Chen et al., 2017; Qin & Li, 2021). Furthermore, Xiong et al. (2022) and Zha et al. (2021) investigated the relationship between the economic growth of tourism and carbon emissions. The results confirmed the significant growth in tourism carbon emissions and the weak decoupling between the sector's economic growth and CO₂ emissions. Cao et al. (2023) investigated the growth rate of the economic benefits of tourism and its water consumption growth rate. They noticed that the tourism water footprint growth rate is lower than the sector's economic growth rate, indicating a weak impact decoupling state.

This paper, therefore, studies decoupling in the nautical tourism industry, focusing on resource decoupling and impact decoupling in nautical ports. It also analyzes the sustainable solutions that ports implement to reduce their environmental footprint. The aim of implementing sustainable strategies and practices in nautical ports and the recreational boating industry is to reduce the consumption of non-renewable resources and the environmental footprint (ES-CIP Consortium, 2015). Thus, this study identifies the strategies and business practices required to improve decoupling in nautical ports and, consequently, across the industry value chain.

METHODS AND MATERIALS

This study aims to determine the relationship between the economic performance of nautical ports and their usage of natural resources. It also seeks to identify strategies for nautical ports aiming to reduce their environmental footprint. It analyzes economic performance using diverse financial and market indicators. The paper uses statistical data on the business performance of nautical ports in Croatia (2009-2022) in order to decouple economic growth and natural resource consumption. The data was collected from the Croatian Bureau of Statistics (CBS, n.d.) for a more extended period and relates to environmental performance (resource usage), market performance (nautical demand), and financial performance (diverse categories of revenues). Based on the data, the growth rate was calculated for variables that represent resource usage (water surface area, land surface area, and length of the coastline equipped for berthing), nautical demand (vessels in transit and vessels on annual berth), and revenues (for berthing services and total revenues). The growth rates were used to analyze and compare the changes in the variables investigated over the observed period so as to evaluate resource decoupling in the nautical ports. The paper proposes a decoupling framework that enables tracing and connecting green and sustainable strategies in the nautical sector with the aim to achieve “resource decoupling” and “impact decoupling”, consequently leading to sustainable development.

RESULTS AND DISCUSSION

Based on statistical data on the business performance of nautical ports in Croatia (2009-2022), in this paper we calculated and compared the ratio between the growth rate of environmental performance, market performance, and financial performance. The growth rate of environmental performance or resource use is calculated using the following indicators: Water Surface Area (WSA), Land Surface Area (LSA), and Length of Seashore Equipped for Berthing (LoSEfB). The growth rate of market performance (nautical demand) is calculated using the indicators of nautical demand: Vessels in Transit (ViT) and Vessels on Annual Berth (ToVaA). The growth rate of financial performance is calculated via revenues using the following indicators: Revenues Vessels in Transit (RevViT), Revenues Vessels on Annual Berth (RevVaA), Revenues Berthing Total (RevBerthTot), and Total Revenues (TotalRev). The growth rates were calculated with 2009 as the beginning year. Table 1 presents the growth rates for all the investigated indicators.

Table 1: Resource use and economic performance of nautical ports (2009 – 2022)

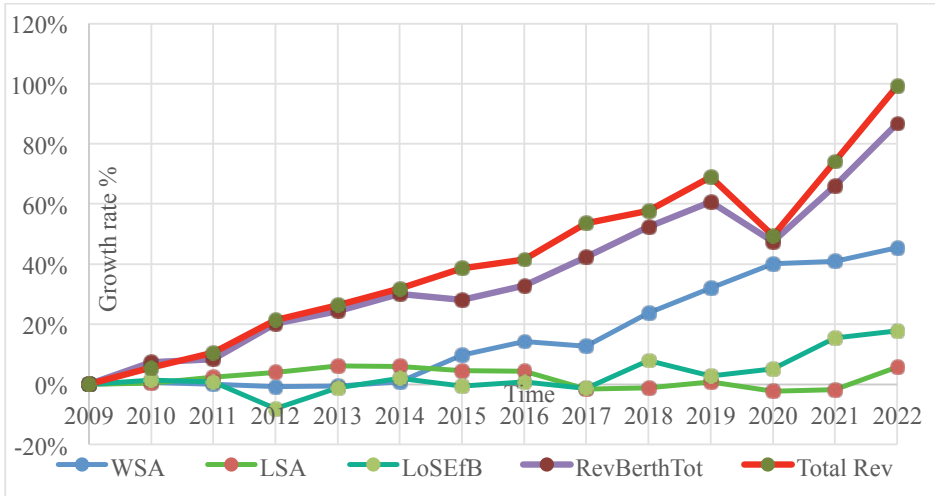
Year	Resources (growth rate)			Economic performance			Financial performance		
	Resource usage			Market performance		RevViT	RevVaA		RevBerth-Tot
	WSA	LSA	LoSEfB	ViT	ToVaA		RevVaA	RevBerth-Tot	
2009	0	0	0	0	0	0	0	0	0
2010	1%	0%	1%	1%	-2%	5%	15%	7%	6%
2011	0%	3%	1%	-8%	-3%	9%	8%	8%	10%
2012	-1%	4%	-8%	-11%	-3%	22%	13%	20%	21%
2013	0%	6%	-1%	-10%	-7%	25%	21%	24%	26%
2014	1%	6%	2%	-11%	-7%	32%	24%	30%	32%
2015	10%	5%	0%	-5%	-9%	29%	23%	28%	39%
2016	14%	4%	1%	-3%	-9%	31%	39%	33%	42%
2017	13%	-2%	-1%	-1%	-9%	40%	53%	42%	53%
2018	24%	-1%	8%	-5%	-8%	50%	61%	52%	58%
2019	32%	1%	3%	0%	-4%	57%	76%	61%	69%
2020	40%	-2%	5%	-40%	-3%	58%	5%	47%	49%
2021	41%	-2%	15%	3%	0%	66%	67%	66%	74%
2022	46%	6%	18%	15%	9%	82%	105%	87%	99%

Legend: WSA - Water Surface Area, LSA - Land Surface Area, LoSEfB - Length of Seashore Equipped for Berthing, ViT - Vessels in Transit, ToVaA - Vessels on Annual Berth, RevViT - Revenues Vessels in Transit, RevVaA - Revenues Vessels on Annual Berth, RevBerthTot - Revenues Berthing Total, TotalRev - Total Revenues.

Source: Authors, based on CBS (n.d.)

Figure 2 shows the growth rates of the resource indicators (WSA, LSA, and LoSEfB) and the revenue indicators (RevBerthTot and TotalRev) for the Croatian nautical ports.

Figure 2: Resource use and revenues of nautical ports - resource decoupling (2009 – 2022)



Source: Authors, based on CBS (n.d.)

The results of the comparison of the previously mentioned indicators confirm that the values of economic performance observed through the revenue growth rate grew faster than the usage of resources in the period from 2009 to 2022. In the analyzed period, nautical ports achieved relative decoupling. Given that a significant increase in demand for marina services was recorded only in the last year of the period analyzed (2022), it is assumed that the growth in revenue in the same period is associated with the growth in consumption among the existing users and the growth in prices of the services in nautical ports. Finally, the results confirm that between 2009 and 2022, the economic activity of nautical ports had a higher growth rate than the growth rate of resource usage.

Based on the literature review, this paper identifies the key actors in the recreational boating service industry and the business solutions for reducing adverse environmental impacts of nautical ports – green and sustainable strategies and practices. The results show that nautical ports increasingly invest in environmentally friendly solutions in order to use resources wisely and reduce their environmental footprint. The comprehensiveness and intensity of sustainable and

green measures in the nautical sector can reduce the environmental footprint at the levels of individual ports and the entire recreational boating industry. Along with the notable growth of economic activities resulting from increased nautical demand, the slowdown in the environmental footprint resulting from green strategies and practices can strengthen impact decoupling in the industry. Implementing green and sustainable strategies and practices can facilitate impact decoupling in the nautical ports and recreational boating industry. Therefore, nautical companies increasingly cooperate with industry stakeholders, governing bodies, environmental organizations, and communities to promote the green and sustainable development of the sector. In addition, many institutions and programs broadly promote the sustainable development of the sector, such as EBI, ICOMIA, ISO, Blue Flag, Green Blue, Blue Marine Foundation, Seabin project, Posidonia Keeper project, International Institute for Climate Action, The Carbon Trust, etc. (ACI Marinas, n.d.; Premier Marinas, n.d.; MDL Marinas, n.d.; The Carbon Trust, 2021; Poletan Jugović, 2022; Innovamarina, 2023).

Table 2 presents the diverse strategies and practices for reducing environmental footprints in the nautical ports sector, grouped according to their specific environment-related impact area (e.g., water consumption, air pollution, energy consumption, etc.). Those strategies and practices enable nautical ports to minimize the adverse impact of their operations on water, land, air, biodiversity and ecosystems, and protect and restore multiple aspects of the complex marine environment.

For example, ACI Club (Adriatic Croatia International Club), a leading Mediterranean marina operator, integrates various green and sustainable solutions across twenty-two marinas (with 6,000 berths) located along the entire Croatian side of the Adriatic coastline. Such solutions include (ACI Marinas, n.d., 2022b) monitoring and optimizing energy and water consumption using the IoT, and setting collectors on the seabed to protect and preserve an endangered clam endemic to the Mediterranean (noble pen shell, *pinna nobilis*). Poletan Jugović et al. (2022) rated all ACI marinas with high use of renewable energy sources (RES) in their analysis of 35 Croatian marinas, indicating their leading position in the energy transition of the sector. ACI Marinas implement recent technological and digital solutions for developing sustainable business models and enabling real-time resource consumption management, digital display of measured data, and smart solutions for monitoring energy and water consumption per pier through automation and sensors (ACI Marinas, 2022a). Another marina group that strives for sustainability is MDL, one of the largest in Europe, which operates 19 marinas and boatyards in the UK and Spain, with over 7,000 berths. MDL marinas implemented diverse solutions, such as

the installation of 1,000 solar panels for on-site generated renewable energy, electric car charging points, 100% electric vehicles for marina operations, LED lighting to enhance energy efficiency with no heat or UV emissions, electric car charging points, electric boat charging, green GYM using eco-power equipment, using Seabins to collect litter from the water and improve water quality, water filtration systems to clean wastewater from boatyard activities, improving local water quality and more (MDL Marinas, n.d.).

Table 2: Green and sustainable strategies and practices for reducing the environmental footprint and resource consumption in the nautical ports industry

Dimensions	Examples of strategies and practices
Water use and water quality management	Reducing water consumption, using desalinated water for operations. Monitoring and controlling water pollution and stormwater runoff from the marina. Preventing solid waste entry into surface waters directly or through storm water or wash. Providing storage facilities for liquid waste to prevent their entry into the water. Cleaning and purifying debris from the water. Adopting nature-based solutions for maintaining water quality. Water management system (wastewater purification, waste oil, ballast water disposal). Using purified wastewater for green areas irrigation and operation.
Marine biodiversity and ecosystem conservation	Monitoring impacts of marina operations on marine biodiversity and ecosystem. Programs for protecting and preserving biodiversity, wildlife, and ecosystem. Eco-friendly boat and marina space cleaning, contingency plans for eco incidents. Enhancing water circulation, reducing stagnation, and promoting natural pollutants. Green landscaping (nature-based solutions, e.g., using native plants and trees). Monitoring impacts of boat mooring and anchoring on sensitive habitats.
Energy efficiency and RES management	Monitoring and reducing energy consumption. Establishing an energy efficiency-related system. Switching to renewable energy sources (RES), installing solar panels/ wind turbines. Energy-efficient lighting and appliances (e.g., shore power supply for boats).

Low-carbon solutions and air quality management	Reducing and preventing air pollution/(GHG) emissions, low carbon solutions. Monitoring and controlling air quality. Building green infrastructures, using greener machinery and fuel. Climate change-related strategies, taking climate action.
Waste and garbage management	Reducing and preventing garbage and waste pollution (solid, liquid, sewage, oil/fuel, paint, marine debris, plastic, chemicals, hazardous materials), using eco materials and products, and making recycling a priority (e.g., using recycling bins). Locating fuel docks to reduce fuel/oil spills; oil spill equipment and oil spill response training; recycling programs for boat parts and materials. Waste and garbage management system (disposal and recycling practices).
Soil and land use and impact management	Monitoring, reducing, and preventing pollution and degradation of nearby soil caused by vessel/equipment maintenance, washing, and handling. Restoring degraded land and soil, including land affected by desertification, drought, and floods/striving to achieve a land degradation-neutral world. Monitoring changes in the proportion of land that is degraded over the total land area. Protecting and restoring sustainable use of terrestrial ecosystems, sustainably managing forests, combatting desertification, and halting land degradation and biodiversity loss.
Other pollution from port operations/vessels	Monitoring, reducing, and preventing pollution from other pollutants (noise, light) generated by port operations and vessels. Controlling the pollution generated by vessels' engines, port operations, and machinery. Controlling artificial light emissions and impacts of light pollution on marine organisms.
Safe working conditions, environmental education, and training	Ensuring safe working conditions, monitoring the safety and security of employees. Inclusiveness, equality, diversity, and anti-discrimination policies. Health care and interpersonal relations; transparent compensation and layoff practices. Seasonal workers' fair contracts and compensation. Environmental education and training of employees, recruiting environmental officers.
Community engagement	Engaging in volunteering work on cleaning beaches/seabed, engaging in community projects, initiatives, and activities, funding local culture and heritage, and human well-being. Assessing impacts on the community's well-being and prosperity.

Source: Authors, based on Lanfranchi et al., 2015; Hojnik et al., 2020; Trstenjak et al., 2020; Akaltan, 2021; Carreño & Lloret, 2021; Martínez-Vázquez et al., 2021; Poletan Jugović, 2021; The Carbon Trust, 2021; ACI Marinas, n.d. 2022a, 2022b; Innovamarina, 2023; MDL marinas, n.d.; Premier Marinas, n.d.

The framework (Figure 3) shows green and sustainable strategies and practices as a solution for practical decoupling actions. Those strategies and practices enable port operators to decrease resource use (e.g., water/water surface area) while increasing economic performance (e.g., revenues). Furthermore, green and sustainable measures enable ports to minimize pollution and other adverse environmental impacts (water pollution, land-related impact, CO₂ emission, adverse impact on biodiversity and ecosystem, etc.), i.e. achieve impact decoupling. The framework can be used as a roadmap for impact decoupling, resource decoupling, and sustainable development in the nautical ports sector, considering the diverse green issues presented in Table 2.

In contrast to the research conducted for this paper, which analyses the decoupling between the economic performance of nautical ports and their usage of marine resources, the previous studies on resource decoupling primarily focused on decoupling between economic growth and water consumption in tourism (Cao et al., 2023). In their comprehensive estimation of water consumption, Cao et al. (2023) determined seven different decoupling states ranging from strong negative decoupling to strong decoupling between economic growth and water consumption in tourism. They revealed that weak decoupling had been present in the most observed period. Similarly, the decoupling between economic growth and resource usage in the nautical ports sector investigated in this paper is relative or weak in the observed period (2009-2022). However, most of the research on decoupling in tourism is focused on decoupling between the growth rate of tourism and carbon footprint or on environmental impact (Lanfranchi et al., 2015; Qin & Li, 2021; Zha et al., 2021; Xiong et al., 2022; Cao et al., 2023). They report on relative or weak decoupling between the growth rate of tourism activity and the growth rate of carbon emission. Furthermore, this paper identifies the green and sustainable strategies and practices that influence the establishment of a more substantial decoupling between resource consumption and/or environmental footprint and economic performance in the recreational boating sector, which corresponds to the previous research and strategies relating to the sustainability of the sector (e.g., Hojnik et al., 2020; Trstenjak et al., 2020; Martínez-Vázquez et al., 2021; Poletan Jugović et al., 2022; Filimon, 2023). Therefore, the findings of this paper and the decoupling framework can facilitate and promote green and sustainable development of the nautical ports and tourism industry.

CONCLUSION

This paper studies the relationship between resource usage and economic growth in order to identify resource decoupling in the nautical industry, using Croatian nautical ports as an example. The research focused on three indicators of resource usage in nautical ports (water surface area, land surface area, and length of the coastline equipped for berthing) and two indicators of their economic growth (revenues for berthing services and total revenues). The results show an increase in both groups of indicators over an extended period. The financial results of nautical ports from 2009 to 2022 showed a higher increase relative to resource usage, revealing significant progress in resource decoupling. In other words, the results revealed relative or weak decoupling between the observed indicators of economic growth and resource usage in the investigated years.

Furthermore, the results showed a continuous increase in resource decoupling, suggesting that nautical ports implement specific green and sustainable strategies and practices so as to minimize their environmental impact and the overuse of marine resources. This paper, therefore, identified such sustainable strategies and practices in the nautical ports sector and classified them into groups related to diverse green and sustainable dimensions (water use and water quality management; marine biodiversity and ecosystem conservation; energy efficiency and renewable energy sources – RES management; low-carbon solutions and air quality management; waste and garbage management; soil and land use, and impact management; other pollution from port operations/vessels; safe working conditions, environmental education, and training; and community engagement). The results suggest that Croatia's largest marina operator, ACI Marinas, broadly implements the various solutions for green and sustainable transition, and plays a leading role in ensuring sustainable development of the nautical sector.

Furthermore, the paper proposes a decoupling framework that enables tracing and connecting green and sustainable strategies and practices in order to achieve resource decoupling and impact decoupling in the nautical sector, consequently leading to sustainable development. Finally, this study indicates the need to integrate decoupling principles in the responsible management of nautical ports and the tourism industry, which is possible by implementing green and sustainable solutions. In addition, cooperation between nautical ports and diverse stakeholders across the industry value chain promotes sustainable development of the nautical tourism industry.

However, the research conducted as part of this paper was limited to a narrow range of indicators aimed at assessing resource decoupling and impact

decoupling. Integrating more resource usage-related, environmental impact-related, and economic growth-related indicators into the assessment would provide a more profound discernment of decoupling in the nautical sector. Therefore, further studies should consider more indicators and research methods in their aim to explore decoupling issues in the nautical sector.

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TOWARDS A SUSTAINABLE EU CIRCULAR ECONOMY THROUGH THE RIGHT-TO-REPAIR DIRECTIVE

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The European Green Deal is one of the main priorities of the EU and its contribution to the UN 2030 Agenda for Sustainable Development. It aims to transform the EU into a climate neutral, resource-efficient, clean and circular economy. One of the core principles of circular economy is extending the lifespan of products, thus reducing waste, as well as avoiding the production of CO2 emissions.

However, according to the European Commission, the premature disposal of consumer goods produces a great amount of CO2-equivalent emissions and generates huge amounts of waste each year. Currently, the majority of customers choose replacement instead of repair, mainly due to a lack of transparency regarding the availability and the conditions of repair, as well as due to rather expensive costs of repair.

Recently, in June 2024, the Right to Repair Directive (R2RD) was adopted as a direct response to the citizens' demands, as expressed in the Conference on the Future of Europe where they proposed launching a repair platform in order to promote sustainable consumption.

The aim of this paper is to point out the key elements of the R2R Directive. The analysis of the Directive will lead to three main conclusions. First, it will be shown that new legislation empowers consumer protection. Second, it will be argued that implementing the Directive has a huge effect on revitalising and strengthening the EU repair market, thus making it a more attractive industry that can create Europe-based quality jobs. Finally, it will be shown that the new regulation highlights the citizens' right to be informed, which is crucial in order to raise awareness about the benefits of repair, and to ultimately contribute to more sustainable consumption and

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circular economy. After all, the question whether a defective but repairable product is repaired or not greatly depends on consumers' behaviour and decision-making. In conclusion, the R2R Directive shows the EU's commitment to empower consumers in the fight against climate change.

Keywords: *right to repair, sustainability, EU, circular economy, consumer protection*

JEL classification: *K12, K15, K32, Q54, Q56*

INTRODUCTION

In the modern age dominated by rapid technological advancement, electronic devices have become integral to our daily life. Consumers simply buy products at an acceptable price from any part of the world. As the number of trade transactions is constantly increasing, the production of goods is continuously rising. When these devices become defective, many customers choose replacement rather than repair. Moreover, the lifecycle of these devices is often limited by built-in obsolescence and restrictive repair practices.

When products are still repairable, meaning they could be repaired and used for much longer, but are rather discarded, we talk about premature disposal. Premature disposal happens in two situations. First, it occurs in situations where consumers still have a right to claim free repair of goods under legal warranty, but rather choose to replace their products. In reality, the majority of EU customers - 65% on average, currently choose replacement and buying a new product even when the product is under legal warranty¹. Second, when the legal warranty does not apply anymore, customers face many challenges related to repair, so they rather buy new products.

As stated by the European Commission, the premature disposal of consumer goods produces 261 million tonnes of CO₂-equivalent emissions, consumes 30 million tonnes of resources, and generates 35 million tonnes of waste annually. Consumers also lose approx. €12 billion yearly by replacing goods rather than repairing them.²

¹ European Commission EC (2018). Behavioural Study on Consumers' Engagement in the Circular Economy. <https://doi.org/10.2818/956512>

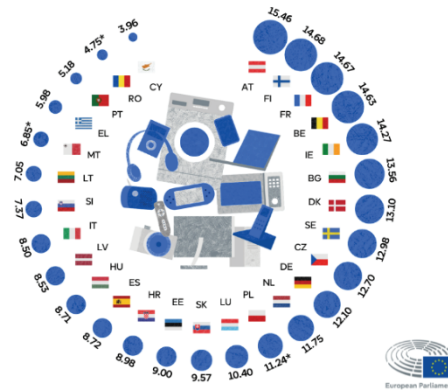
² European Commission, (2023). Impact assessment report; Accompanying the document Proposal for a Directive of the European Parliament and of the Council on common rules promoting the repair of goods and amending Regulation (EU)2017/2394, Directives (EU) 2019/771 and (EU) 2020/1828

In addition, Europeans are the biggest producers of e-waste, which is one of the fastest growing waste streams in Europe, but also in the world.

Figure 1: Find out how many kilos of electronic equipment have been collected per inhabitant in each EU country

How much e-waste do EU countries collect?

Electric and electronic equipment waste,
in kg per inhabitant



Source: Eurostat, 2021; www.europarl.europa.eu

However, a hope lies in the research which shows that 77% of the surveyed consumers did consider repairing broken goods before purchasing new ones³. There are various reasons why consumers tend to choose replacement over repair at the end. The price has been identified as the main barrier to repair (Lopez-Bermúdez and Vence, 2024), particularly the ratio of the repair costs to replacement costs (Terry, 2019). The European Commission found that the willingness to repair significantly drops when the price of repair reaches around 20% of the cost of a new product.⁴ There is a big shortage of spare parts on the market as products are designed in a way which makes repair almost impossible. In utilizing software integration and software technological protection measures - TPMs, many product designs now allow manufacturers

³ Eurobarometer, 2020.

⁴ European Commission, (2023). Impact assessment report; Accompanying the document Proposal for a Directive of the European Parliament and of the Council on common rules promoting the repair of goods and amending Regulation (EU) 2017/2394, Directives (EU) 2019/771 and (EU) 2020/1828

to retain considerable control over the manner of repair and choice of technicians (Rosborough, 2020). The high price of spare parts further discourages repairs (Ackermann et al., 2018). One typical reason why spare parts can be very costly is a practice called bundling⁵. This means that manufacturers often offer spare parts as part of assemblies rather than individually. Furthermore, repair is time consuming. Additionally, there is a lack of information about repair, not only for one specific item, but also in terms of general awareness of the importance of repair, which would positively influence customers' decision-making and minimize the power of fashion obsolescence, meaning that products often lose their appeal because new products have appeared in the market – thus encouraging customers to replace their products in the search for novelty (Lopez-Bermúdez and Vence, 2024). For instance, consumers frequently discard old smartphones not because they are broken and repair is too costly, but simply because they want to own the latest model (Shapira, 2024).

Consumers play a crucial role in fostering sustainable consumption as their willingness to repair can significantly reduce the environmental impact of products. Cultivating a willingness to repair among consumers seems to be the greatest challenge (Roskladka, Jaegler, Miragliotta, 2023).

EU consumers can be categorized into four groups based on their willingness to repair: 1) enthusiastic repairers are consumers who repaired their product and showed a strong inclination toward repairs (13.4%); 2) reluctant repairers are consumers who repaired their products, but exhibited a lower affinity to repair (37.8%); 3) enthusiastic replacers (39.5%) are individuals who replaced defective products, but showed little interest in repair; and 4) reluctant replacers (9.2%) are consumers who replaced defective products despite having a strong interest in repair.

This last group highlights the market and system failure, because these consumers were aware of the importance of repair, but were effectively forced to replace their products due to all of the previously mentioned reasons.⁶

Several decades of global hyperproduction and hyperconsumption of goods have already led to severe environmental pollution. Based on recent negative data, future proof consumer law must prioritize not only economic interests but also sustainability. This shift is essential, even though consumer

⁵ Right to Repair: The Price Is Not Right, <https://repair.eu/news/the-price-is-not-right/>

⁶ Source: European Commission, (2023). Impact assessment report; Accompanying the document Proposal for a Directive of the European Parliament and of the Council on common rules promoting the repair of goods and amending Regulation (EU)2017/2394, Directives (EU) 2019/771 and (EU) 2020/1828

laws have traditionally focused on the protection of the economic rights of consumers without fully addressing the environmental consequences of such rights (Terryn, 2019). Premature disposal of consumer goods now threatens the consumers' right to a healthy and sustainable environment, which is one of the eight basic rights of consumers established by the UN⁷.

In an attempt to address the environmental harms caused by premature disposal, recent years have seen a resurgence in community and collective repair initiatives (Rosborough, 2022). Efforts such as creation of repair cafés and tool libraries have made repair activities more accessible, while organizations like iFixit have helped spread knowledge and expertise. These initiatives have also contributed to raising public awareness and promoting repair culture.⁸

The European Union and its policymakers had to urgently intervene by setting up a new legal framework to tackle this important issue⁹. What is more, the need to protect sustainable consumption and the consumers' right to repair was so strong that it required the adoption of imperative legal norms such as the Right to Repair Directive¹⁰ (Jovičić, 2024).

The Directive aligns with the European Green Deal, one of the EU's main priorities, which supports the UN 2030 Agenda for Sustainable Development. It aims to transition Europe to a climate-neutral, resource-efficient, clean and circular economy by 2050.¹¹ One key element of circular economy is improving the sustainable consumption of goods by expanding the lifespan of products. That is exactly the goal of the Right to Repair Directive, which is why it represents a critical response to the environmental and social challenges posed by the modern consumption habits. The directive also aligns with the United Nations' Sustainable Development Goals, particularly Goal 12: Responsible Consumption and Production, which is focused on ensuring sustainable con-

⁷ Resolution of the UN General Assembly, no. 29/248, 1985.

⁸ In 2024, the first Repair Cafe, opened by Martine Postma in 2009 in Amsterdam, marks its 15th anniversary. In comparison, today there are over 2,500 Repair Cafés worldwide, <https://www.repaircafe.org/en/about/>

⁹ The importance of circular economy to the European Union is evident in the fact that the new mandate of European Commission started on 1 December 2024, and for the first time ever the European Union has one Commissioner in charge of circular economy, Ms Jessika Roswall.

¹⁰ Directive (EU) 2024/1799 of the European Parliament and of the Council of 13 June 2024 on common rules promoting the repair of goods and amending Regulation (EU) 2017/2394 and Directives (EU) 2019/771 and (EU) 2020/1828

¹¹ European Commission, (2019). Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. The European Green Deal

sumption and production patterns by promoting resource and efficiency, reducing environmental degradation, and building collaborative relationships between stakeholders throughout the consumption production system.¹²

Additionally, the directive complements other recent EU legislation, such as the Ecodesign Directive¹³ and Directive Empowering Consumers for the Green Transition.¹⁴ It is important to note that new legislation reflects citizens' demands, as highlighted during the Conference on the Future of Europe where citizens proposed ideas that are now incorporated in the Directive, an example being the idea of launching a European online repair platform.¹⁵ Actually, the adoption of the Directive was initiated from the bottom-up approach, starting with citizens united in the Right to Repair Coalition team¹⁶ who worked on this topic for years. This Coalition plays a key role even now, in the implementation of the procedure.

Finally, the Right to Repair Directive was proposed by the European Commission on 22nd March 2023, after being previously announced as part of the New Consumer Agenda, a component of the New Circular Economy Action Plan for a cleaner and more competitive Europe, which was presented in March 2020 as one of the policy pillars of the European Green Deal. After the huge support¹⁷ in the plenary vote of the European Parliament on 23 April 2024, the Directive of the European Parliament and of the Council on common rules promoting the repair of goods and amending Regulation (EU) 2017/2394, Directives (EU) 2019/771 and (EU) 2020/1828¹⁸ was adopted on 13 June 2024,

¹² UN, (2015). Transforming our world: the 2030 Agenda for Sustainable Development, <https://sdgs.un.org/2030agenda>

¹³ Regulation (EU) 2024/1781 of the European Parliament and of the Council of 13 June 2024, establishing a framework for the setting of ecodesign requirements for sustainable products, amending Directive (EU) 2020/1828 and Regulation (EU) 2023/1542 and repealing Directive 2009/125/EC

¹⁴ Directive (EU) 2024/825 of the European Parliament and of the Council of 28 February 2024 amending Directives 2005/29/EC and 2011/83/EU as regards empowering consumers for the green transition through better protection against unfair practices and through better information

¹⁵ Conference on the Future of Europe, (2022). Report on final outcome

¹⁶ The Right to Repair Europe coalition represents over 170 organisations from 27 European countries. It includes environmental NGOs and repair actors such as community repair groups, social economy actors, spare parts distributors, self-repairers, repair and refurbishing businesses, and any citizens who would like to advocate for their right to repair; <https://repair.eu/about/>

¹⁷ A large majority of MEPs – 584 out of a total of 705 members – voted in favour.

¹⁸ Commonly referred to as the Right to Repair Directive

and it entered into force on 30 July 2024. Now the ball is in the court of the Member States who will have 24 months to transpose the Directive into national rules, until 31 July 2026.

KEY ELEMENTS OF THE DIRECTIVE

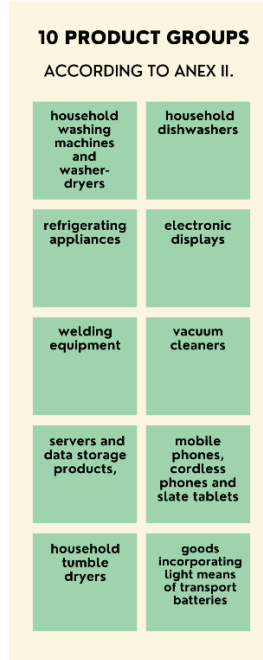
The Directive can be structured into four key points: obligation to repair, extension of legal guarantee after repair, launching of European online repair platform and obligatory national measures promoting repair. While the first three key elements focus on consumers' right to repair as well as the development of the repair market, the final element highlights the right to be informed about the right to repair as a crucial prerequisite for the full implementation of this Directive.

Since divergence in national laws and the supposed effects on the internal market have been used as justifications for the “full harmonisation” character of the Directive on common rules promoting the repair of goods (Lopez, 2024.), in the following text the author will provide a more detailed analysis of the key provisions, along with criticisms and comments regarding certain unclear solutions.

AN OBLIGATION TO REPAIR

Article 5 of the Directive establishes an ‘obligation to repair’ for manufacturers of goods which are technically repairable under the EU law, meaning that the obligation only applies to products listed in the Directive’s Annex II, which currently includes only 10 product groups. Those are products for which reparability is regulated by the recently adopted Ecodesign for Sustainable Product Regulation, such as large household appliances, excluding many other commonly used items. The limited scope of goods covered by the Directive is its biggest shortcoming. However, it is explained that the list of products to which the obligation to repair will be applicable will be updated by the European Commission on an annual basis, as more ecodesign requirements on repair are adopted.

Figure 2: List of 10 product groups for which the Right to Repair Directive will be applicable



Source: Author, based on Annex II of the Right to Repair Directive

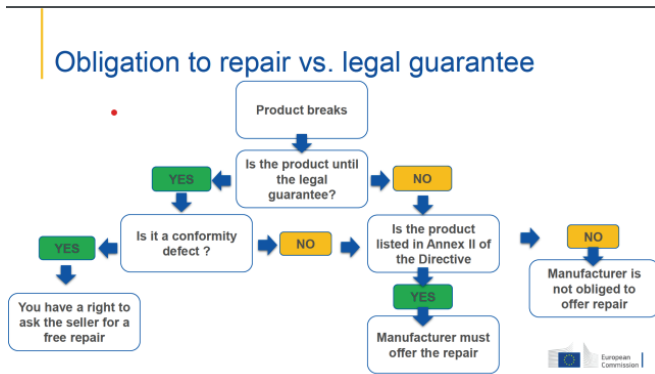
Later in the text of the same article, it is stated that the repair obligation is to be “carried out either free of charge or for a reasonable price”. Furthermore, it is stated that spare parts and tools have to be offered at a reasonable price. However, it is not specified what “reasonable” means, thus making this provision legally weak and criticized by all key stakeholders. To avoid different interpretations of this provision by national courts which could lead to legal uncertainty and inconsistency, the European Commission should promptly issue guidelines and further clarify what constitutes a reasonable price.

In order to strengthen the consumer rights to repair, this article prohibits manufacturers from using techniques preventing repair, such as falsely claiming that repair is unsafe, or using software which makes repair almost impossible, or refusing repair just because a previous repair has been performed by “non-authorised” repairers.

EXTENSION OF THE LEGAL GUARANTEE AFTER REPAIR

In order to encourage repair and deprioritize the replacement of goods, the Directive stipulates that the seller's or professional's liability period may be extended by one year after a defective product is repaired. Member States will have the option to implement even longer extensions to the liability period, which is good for consumers, but could lead to significant differences between Member States and to consumer dissatisfaction, which is why the European Union should monitor this regulation and provide guidelines for the regulation of the warranty period.

Figure 3: Infographic on the obligation to repair vs. legal guarantee



Source: Presentation by the European Commission at the stakeholder workshop, November 2024; www.commission.europa.eu

Another new obligation for the sellers arises from the Directive, requiring them to inform consumers about their right to choose between repair and replacement, as well as the extension of the liability period if they opt for repair. This aims to raise awareness of both alternatives and highlight the benefit of choosing repair. That information requirement would encourage sustainable consumption and contribute to a circular economy. This obligation is very important, bearing in mind that, based on the Consumer Market study from 2016 conducted by the European Commission, only 56% of consumers knew that they have the right to a free repair or replacement when their refrigerator breaks down 20 months after the purchase date. The lack of awareness of the two-year guarantee period is a potential source of consumer detriment.¹⁹

¹⁹ https://commission.europa.eu/system/files/2018-05/legal-guarantees-final-report_en.pdf

In addition, many studies show that the reason for the weak importance of consumer guarantees and warranties lies in the poor market information of consumers about their benefits, which points to a greater need for better knowledge (Dunković & Knežević, 2024).

Another novelty according to the Directive is that, depending on the specific characteristics of the relevant category of goods, the seller could provide the consumer with a replacement item if the repair is not completed within a reasonable time frame or if it causes significant inconvenience. This replacement good could also be a refurbished good. In any case, the replacement good temporarily loaned to the consumer should be free of charge. Again, it is not specified in the Directive what “reasonable time” means, leaving the door open for different interpretations.

EUROPEAN ONLINE REPAIR PLATFORM

Article 7 of the Directive requires the Commission to develop an EU online repair platform, which is envisioned as a centralized digital hub designed to support and promote repair activities across Europe, as proposed by citizens and repair activists.

The European online platform should allow consumers to find suitable repair services for their defective goods and, where applicable, sellers of refurbished goods, purchasers of defective goods for refurbishment or community-led repair initiatives such as repair cafés. For the first time ever, the word “repair café” is mentioned in a binding legal document, and this represents a big moment for the culture of repair cafés.

The platform will be free for citizens and will serve as a resource for comparing repair costs, service availability and repairability ratings of products, empowering consumers to make informed decisions. Member States have to manage their own national sections on the platform. The European Commission has to develop an online common interface until 31 July 2027, and it has to be fully operational as of 1 January 2028.

Bearing in mind that repair is a labour-intensive and strongly territorialized activity, the new legislation can help foster the development of local and regional economies and can enhance their capabilities (Lopez-Bermúdez and Vence, 2023). By launching the European online repair platform, the Right to Repair Directive is stimulating new business opportunities in the repair sector, thus creating potential for Europe-based jobs in the repair sector by boosting demand for skilled repair services. However, there are many opinions stating

that the ones with the most benefit will again be the manufacturers who, by not making parts and tools available, will create repair monopolies and hurt small businesses. According to a recent survey by iFixit, 96% of independent repair shops stated that they had to turn customers away because of repair restrictions.²⁰ However, the new legislation should support small and medium-sized enterprises by offering them a digital marketplace to expand their customer base. The potential for economic growth in the repair market is substantial, with national initiatives like repair cafés and technical service providers benefiting from this legislation. The new rules are expected to bring €4.8 billion in growth and investment within the EU²¹ (European Commission, 2023).

NATIONAL MEASURES PROMOTING REPAIR

Under Article 13 of the Directive, the Member States should implement at least one national measure promoting repair. This provision is a response to the huge lack of awareness on the importance of repair and sustainable consumption. National measures could take the form of repair vouchers, repair funds, online platforms for repair, training programs or taxation measures. Once again, this provision ensures importance and visibility to repair cafés, which are now seen as the centres of learning and promoters of the repair sector.²²

However, various EU Member States have already introduced their own initiatives and measures promoting repair. National measures promoting repair play a crucial role in bridging the gaps left by the EU-level provisions and fostering a culture of repair across the Member States. This provision gives hope to many repair activists that national ambitions will rise above the EU ones in this case, to make the right to repair a reality in Europe. On the other

²⁰ <https://www.ifixit.com/Right-to-Repair>

²¹ European Commission, (2023). Impact assessment report; Accompanying the document Proposal for a Directive of the European Parliament and of the Council on common rules promoting the repair of goods and amending Regulation (EU)2017/2394, Directives (EU) 2019/771 and (EU) 2020/1828

²² In the Interview *Repair cafés as centres of learning for a sustainable life* professor Caroline Gingleiter from the University of Klagenfurt, who also initiated a repair café herself, examined the question of how lifelong learning can contribute to a good, mindful, and sustainable life. To this end, she investigated repair cafés as centres of learning in her dissertation, <https://epale.ec.europa.eu/en/blog/epale-interview-repair-cafes-centres-learning-sustainable-life>

hand, these differences in national laws and their potential impact on the internal market have been used as justifications for the “full harmonisation” character of the Directive on common rules promoting the repair of goods (Lopez & Vence, 2024). The most transparent measure for consumers might be the one implemented by the French government in 2021, when France established a reparability index for five product categories (smartphones, laptops, televisions, washing machines and lawnmowers). This index needs to be calculated by the manufacturer according to a rule and included on the product labels.²³

IMPLEMENTATION

The Member States will have 24 months to transpose the Directive into national legislation, until 31 July 2026. Even though the Directive proposal to promote repair is based on the argument that having different national legislations creates obstacles for the functioning of the Common Market, due to some legally weak and vague provisions the Directive relies heavily on national governments for its implementation and enforcement. This could lead to inconsistencies across EU Member States, creating disparities in consumer rights. The full extent of the right to repair may indeed vary between jurisdictions even though the Directive forbids Member States from maintaining or introducing diverging national provisions. That is why its implementation will require collaboration among stakeholders. A good approach is organising various workshops and consultations with all stakeholders on national, regional and European levels²⁴. In addition, the fact that Annex II is an open document that will be updated over time shows that the implementation will require ongoing adaptations to technological advancements.

²³ According to Spareka, a French company helping consumers repair their appliances by offering video tutorials, diagnostic tools and the sale of spare parts on their platform called “l’indice de réparabilité”, in only one year the amount of products subscribing to the index in France increased by almost 20%. <https://www.eea.europa.eu/en/circularity/thematic-metrics/business/data-on-products-evaluated-against-the-french-reparability-index-1>

²⁴ For example, on 12 November 2024 the Directorate General for Justice and Consumers of the European Commission organised an online workshop for stakeholders. The purpose of the workshop was to exchange information with the stakeholders about the practical implementation of the new rules. Around 200 participants joined the meeting, including the author of this paper. Many questions and concerns were raised which shows that implementation is an ongoing process with several open questions remaining, especially bearing in mind that the European online repair platform still has to be developed, https://commission.europa.eu/ec-events/right-repair-stakeholder-workshop-2024-11-12_en

THE ROLE OF CASE LAW IN STRENGTHENING THE RIGHT TO REPAIR

The Right to Repair (R2R) Directive marks a significant step in the European Union's commitment to a circular economy. However, to fully assess its impact, it is essential to place it within a broader global and comparative context. This chapter expands on the discussion by analysing how the EU's approach differs from similar policies in other jurisdictions, particularly the United States and the United Kingdom.

The US approach to the right to repair has been characterised by a patchwork of state-level legislation rather than a unified federal policy. While organizations such as the Federal Trade Commission (FTC) have supported repair rights, manufacturers have often resisted legislative efforts. A key legal precedent in this area is the case *FTC v. Deere & Co. (2025)*, where the FTC challenged John Deere's restrictive software policies that prevented farmers from repairing their own machinery²⁵. The case underscored the tension between intellectual property rights and consumer rights, with the ruling ultimately favouring broader repair access²⁶. Despite the ruling, the US repair landscape remains fragmented, with some states enacting stronger repair laws, while others face lobbying pressures from manufacturers. Unlike the EU's Directive, the US lacks a comprehensive legal framework that mandates repairability across product categories.

Following Brexit, the UK has maintained elements of the EU's sustainability agenda, but has not yet implemented an equivalent to the R2R Directive. The UK's approach is largely governed by consumer protection laws and voluntary industry commitments. The case *Dyson Ltd v. Qualtex (UK) Ltd. (2006)* illustrates the complexities of repair rights in the UK.²⁷ In this case, Dyson sued Qualtex for producing spare parts for Dyson vacuum cleaners without authorisation. The ruling favoured Dyson, limiting the availability of third-party spare parts and demonstrating the challenges of promoting the repair culture in a market with strong intellectual property protections. The UK government has introduced new eco-design requirements similar to those in the EU, mandating that spare parts for certain products be made available. However, without a dedicated R2R law, consumers in the UK face barriers similar to those in the US, where manufacturers retain significant control over repair processes.

²⁵ Federal Trade Commission, 2025: FTC, States Sue Deere & Company to Protect Farmers from Unfair Corporate Tactics, High Repair Costs | Federal Trade Commission

²⁶ Case: 3:25-cv-50017 Document, "Deere & Company, FTC v.

²⁷ World Intellectual Property Organization (WIPO), 2006: WIPO Lex

Judicial decisions play a crucial role in shaping the implementation and effectiveness of repair rights. The cases discussed above highlight how courts have navigated the balance between corporate interests and consumer rights. In the EU, the R2R Directive's legal framework provides stronger protections compared to the US and UK, but case law will still be instrumental in clarifying ambiguities such as the definition of "reasonable repair costs" and the scope of manufacturers' obligations. Future research should incorporate further analyses of case law developments, particularly relating to how national courts interpret the Directive's provisions once implemented by the Member States.

CONCLUSION

The Right to Repair Directive is a pivotal step toward addressing the environmental and social challenges posed by modern consumption patterns. It aligns with the European Union's broader goals of transitioning to a circular economy, as stated in the European Green Deal. By empowering consumers, enhancing transparency, and fostering the development of the repair market, the Directive holds the potential to significantly extend product lifespans, reduce CO2 emissions and create Europe-based quality jobs in the repair sector.

Despite its potential, the Directive is not without its limitations. While it establishes important principles such as the obligation to repair, the extension of legal guarantee after repair and the creation of a European online repair platform, certain provisions remain vague and legally weak, particularly those regarding the scope of the products covered and the definition of "reasonable" repair costs. These ambiguities could lead to inconsistencies in its implementation across Member States, potentially undermining the Directive's effectiveness.

Despite these challenges, the Directive represents a significant policy innovation. It responds to the growing public demand for sustainable consumption and reflects a bottom-up approach, with citizens and advocacy groups playing a key role in its development. Initiatives such as repair cafés, tool libraries, and the forthcoming European online repair platform demonstrate the potential for repair to become a mainstream activity, fostering local economies and reducing environmental impacts.

Looking ahead, the success of the Right to Repair Directive will depend on its effective implementation, which requires good and intensive collaboration between the European Commission, Member States and all stakeholders. This includes providing clear guidelines, updating the list of covered products

and most importantly – raising public awareness about the benefits of repair. If these challenges are met, the Directive could serve as a global model. Indeed, the European approach with focus on ecodesign requirements also proactively shapes product design by insisting on devices being built to facilitate repair. Given the size of the European market, manufacturers may apply these new standards globally (Perzanowski, 2021).

While the road to achieving these goals remains long and uncertain, the Directive represents a crucial milestone in this transition, demonstrating the EU's commitment to empowering consumers and combatting climate change.

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AGE OF SCHOOL ENTRY, HUMAN CAPITAL FORMATION, AND LABOUR MARKET OUTCOMES: LESSONS FROM CROATIA

Ivan ŽILIĆ*

This study examines the impact of school starting age on educational attainment and labour market outcomes in Croatia, a key issue in policy discussions on human capital formation. While starting school at an older age can enhance academic performance due to greater relative and absolute maturity, it leads to delayed entry into the labour market, thus postponing potential economic benefits. Conversely, younger students may face challenges such as negative peer effects and lower self-esteem, which can impact academic success. However, they benefit from earlier workforce entry and potentially different educational trajectories. Using Croatia's school-starting rules from 1950-1975 as a quasi-natural experiment, we analyse the effects of starting age on the outcomes for individuals born from January to December. In this period, children started school in the year they turned seven, creating a sharp month-of-birth cutoff: children born in December were nearly a year younger than their January-born peers within the same cohort. This policy allows us to address the endogeneity of starting age and isolate its effects on later outcomes. Our analysis leverages pooled data from the Croatian Labour Force Survey (2007-2018) and employs both intent-to-treat and instrumental variable regressions to estimate the causal effects of school starting age on educational and labour market outcomes. The results indicate that younger students have a slight advantage in educational attainment, showing slightly higher years of schooling, particularly among women, likely due to lower opportunity costs of continued education. This finding contrasts with

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much of the existing literature, which often suggests academic benefits for older starters; however, it aligns with research showing that younger students may ultimately complete more schooling (e.g., Dobkin and Ferreira, 2009). Regarding labour market outcomes, younger students exhibit higher employment rates during the survey period. This may stem from their educational advantage or earlier workforce entry. The gender-specific results suggest that women, in particular, in educational terms gain more from starting younger, which may reflect societal and economic incentives influencing career decisions. These findings underscore the importance of considering both the gender and the trade-offs between academic and economic outcomes when setting policies around school starting age.

Keywords: *school starting age, years of schooling, labour market, evaluation, Croatia*

JEL classification: *I21, J24, P20*

INTRODUCTION

What are the effects of school starting age on educational performance and the subsequent labour market outcomes, and is there an optimal school starting age that maximizes human capital accumulation? This question is central to ongoing academic and policy debates. Starting school at an older age can offer advantages, such as enhanced curriculum absorption and the benefits of absolute and relative maturity, which may lead to improved academic performance. However, delaying the start of formal education also postpones entry into the labour market, creating uncertainty about the overall impact on long-term economic outcomes. These considerations highlight important trade-offs. Absolute age maturity implies that older students are more cognitively prepared, which can improve their ability to learn and succeed academically. Relative age maturity, meanwhile, implies that being older compared to peers can boost confidence and relative performance, providing these students with an advantage. However, these benefits may come at the cost of younger students facing negative peer effects and potential disadvantages in self-esteem and academic achievement, along with a delayed transition to the workforce for older starters. Indeed, research shows that older children perform better on exams (Fredriksson and Ockert, 2005), while the effects on labour outcomes are mixed, with some initial negative impacts on earnings that tend to decrease

over time (Black et al., 2008). Building on these insights, in this paper we investigate the impact of school starting age on educational performance and labour market outcomes by exploring school-starting rules in Croatia from 1950 to 1975. In particular, we test the hypothesis that age of school entry is an important determinant in the accumulation of human capital. To circumvent the endogeneity of school starting age, we use school starting rules as a source of exogenous variation. In particular, during the analysed period, children enrolled school in the year when they turned seven, which implies a sharp month-of-birth discontinuity in the school starting age: children born in December are almost a year younger than their cohort-peers born in January. Using these administrative rules in combination with pooled Croatian Labour Force Survey 2007- 2018, we estimated the intent-to-treat as well as instrumental variable regression to capture the effect of the school starting age on educational and labour market outcomes. The findings suggest that being younger within a school cohort provides a modest educational advantage, as younger students tend to have slightly more years of schooling compared to their older peers, particularly among women. This advantage appears to be driven by the lower opportunity cost of continuing education for younger students. These results contrast with much of the existing literature, which often indicates that older school starters perform better academically due to greater maturity and school readiness. However, consistent with Dobkin and Ferreira's (2009) findings, this study demonstrates that younger students may ultimately attain higher educational levels, despite facing initial academic challenges. Regarding labour market outcomes, the results indicate that relatively younger students within a cohort have a higher likelihood of being employed during the survey period. This may be a consequence of their educational advantage and/or earlier entry into the labour market. Given these complexities, it is essential for policymakers and educators to carefully consider the implications of school starting age in order to optimize both educational attainment, human capital accumulation, and economic outcomes. The contributions of this paper are twofold. First, we provide new evidence from Croatia by leveraging school entry rules and employing intent-to-treat and instrumental variable regressions using data from the Croatian Labour Force Survey (2007-2018) to identify the causal effect of school starting age. Second, we highlight the gender-specific impacts, showing that the educational advantage of starting school younger is particularly pronounced for women, offering a nuanced perspective for policy discussions.

LITERATURE REVIEW

Research on the impact of school starting age on the educational and labour market outcomes reveals that while starting school at an older age generally leads to better academic performance and higher educational attainment, the effects on long-term labour market outcomes are less consistent. However, there is no clear consensus in the literature with regard to the school-starting age effects, as the results are conditional on educational context and aggerated by the identification issues. For example, Fertig and Kluve (2005) studied the impact of school starting age on educational outcomes in Germany and found that older school entrants are more likely to face negative outcomes, such as repeating a grade or obtaining lower-level degrees. However, after accounting for unobserved differences between early and late entrants using a cut-off date rule, they found no significant impact of age at school entry on educational performance. On the other hand, Fredriksson and Ockert (2005) showed that children who start school at an older age perform better academically and attain higher levels of education. This effect is particularly pronounced for children from families with weaker educational background. Although the long-run earnings effects are positive, the overall net effect on lifetime earnings is negative due to the opportunity cost of entering the labour market later. The study concludes that these outcomes are driven more by absolute maturity rather than relative age within the class. Black et al. (2008), exploring the long-run effects of school starting age using data from Norway, found minimal long-term effects on educational attainment, IQ scores, or earnings. They also highlighted short-term benefits on the labour market that diminish over time as individuals gain more work experience. Kawaguchi (2009) found similar results in Japan, where older children achieved higher test scores and educational attainment, translating into higher earnings for males. This underscores the importance of maturity at school entry for academic and labour market success. Similarly, Kaila (2017) in Finland documented that students born just after the cut-off date for school entry have higher GPAs and are more likely to complete upper secondary education, with stronger effects among females. Dobkin and Ferreira (2009), analysing the educational system in the United States, found that while younger students generally perform worse academically, they tend to attain higher educational levels. However, this increased educational attainment does not lead to better labour market outcomes, as there is no significant effect on wages or employment probability. Oosterbeek et al. (2020) studied the effects of school starting age in the Netherlands, where early ability tracking is common. They found that children born

just after the school entry threshold perform better in primary school and are more likely to place in high-ability tracks. However, these advantages diminish over time, with no significant effect on the highest educational level attained or long-term labour market outcomes. Balestra et al. (2019) highlighted the role of child development as a gradient of school-starting age effects, showing that older school starters are less likely to require special educational services and have fewer behavioural issues, leading to better academic performance throughout compulsory schooling. However, these benefits do not necessarily extend to employment or earnings. In summary, while starting school at an older age tends to improve academic performance and educational attainment, the impact on long-term labour market outcomes is inconsistent and depends on various educational and contextual factors. The lack of a clear consensus on the effects of school starting age may stem from the varying educational systems represented in the existing research. For instance, Germany, the Netherlands, and Croatia implement early tracking into academic or vocational pathways, whereas Finland postpones tracking until age 16, prioritizing equity and teacher autonomy. Japan features a competitive, centralized system with tracking beginning in high school, while the USA adopts a more flexible, informal approach. Notably, Germany and the Netherlands excel in vocational training, while Finland and Japan strike a balance between strong academics and vocational preparation. These differences not only help to explain some of the divergent findings in the literature, but also underscore the necessity for further research examining the impact of school starting age within diverse educational contexts.

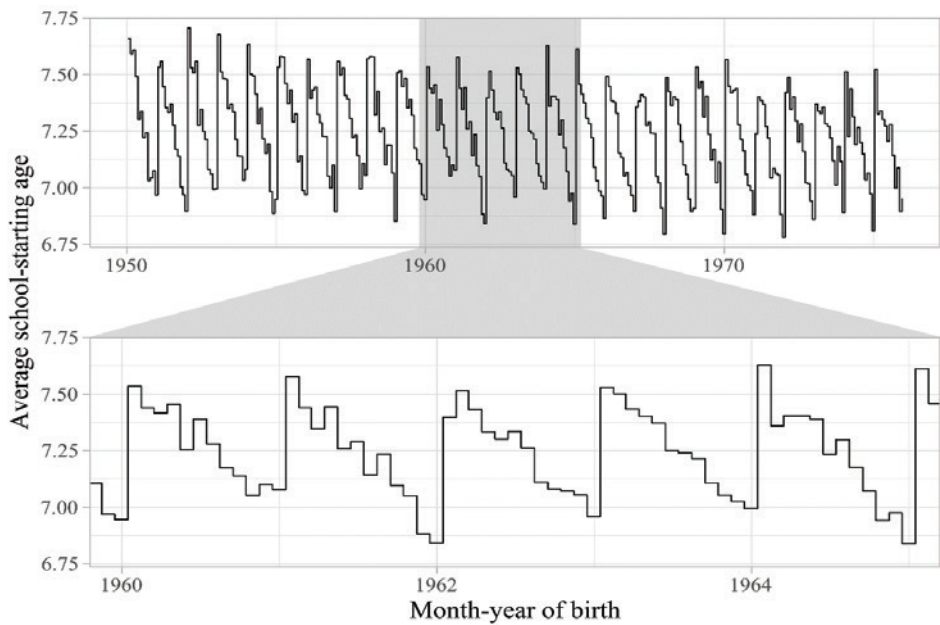
DATA AND METHODOLOGY

Data were obtained by pooling the 2007–2018 versions of the cross-sectional Croatian Labour Force Survey (LFS), which contain demographic characteristics, education variables and labour market outcomes. In our analysis, we focus on individuals born between 1950 and 1975, both inclusive, when the age cut-off for the school-start was 1st of January. The most important variable, the school starting age, is not explicitly available in the data, but can be proxied using other information in the dataset. In particular, LFS provides data on the month-year of birth, years of education, and year of finished education, from which school starting age can be constructed: assuming that there is no grade retention and no grade skipping, school-starting age is calculated as a difference between age and years of education. Given that the school-starting

age is of pivotal information in our analysis, we present several visual and tabular inspections of this statistics’ validity: Figures 1 to 4 and Table 1.

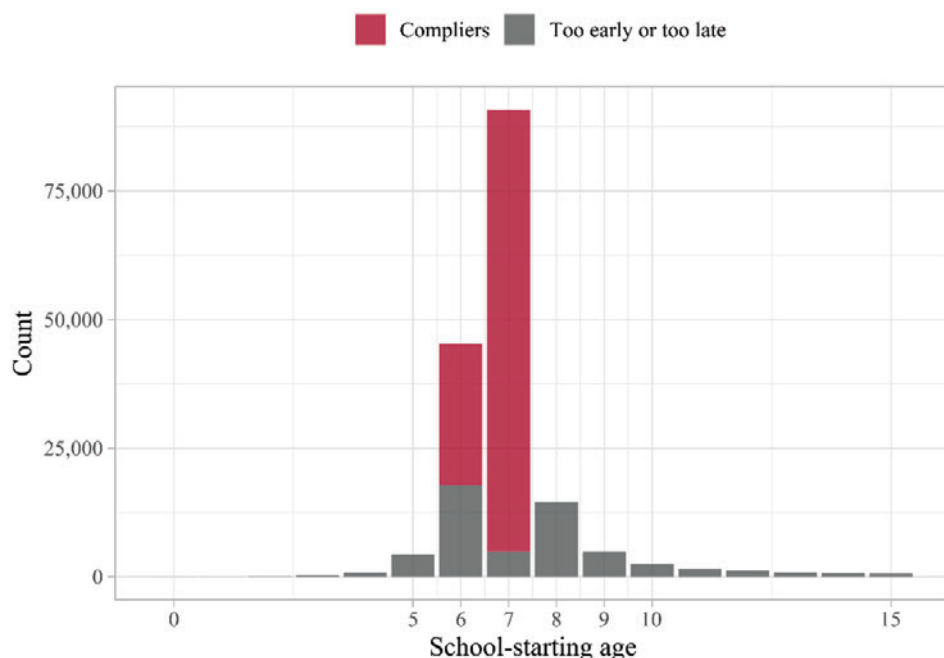
While our constructed measure does not yield perfect information on the school-starting age as an individual might be retained in a grade, skip it, or have gaps in the educational tenure (for example, complete high school, work for some time, and then start university), a descriptive analysis indicates that this measure yields an expected school-starting age profile – sharp December-January discontinuity, as shown in Figure 1. This discontinuity comes from administrative elementary school entry rules, and it also means that children born in December should start school almost a year younger than children born in January – and most of them do. Compliance to the school-starting age can be seen in Figure 2, which shows that most children in the analysed cohorts do follow administrated school-starting rules.

Figure 1: Average school-starting age by month-year of birth



Notes: The sample is restricted to individuals starting school from 4 to 9 years old (proxy measure). Source: Labour Force Surveys 2007-2018 and author’s own calculations.

Figure 2: Histogram of school-starting age



Notes: The sample is restricted to individuals starting school from 4 to 9 years old (proxy measure). Source: Labour Force Surveys 2007-2018 and author's own calculations.

In addition, Table 1 presents the portion of individuals who start school in compliance with the administratively set age rules. We show the portion of compliers, as well as the portion of individuals who start school too young and too old for two subsamples: the full one, and the one where the proxied school-starting age is filtered from 4 to 9 years old. There are several, arguably intuitive, insights; in particular, looking at columns one to four, one can observe the following: (i) complier portion by months is inversely U-shaped – children born in the middle of the year are more likely to start school when they are supposed to, which is expected; (ii) the portion of children starting school too young is decreasing in relation to the month of birth, which again is intuitive – a child born in December will be relatively young in a cohort anyway, it makes less sense to non-comply to administrated rules and send them to school earlier; (iii) inversely, the portion of children starting school too old is increasing in relation to the month of birth – a bigger portion of children starts school too old if they are born in December than in January.

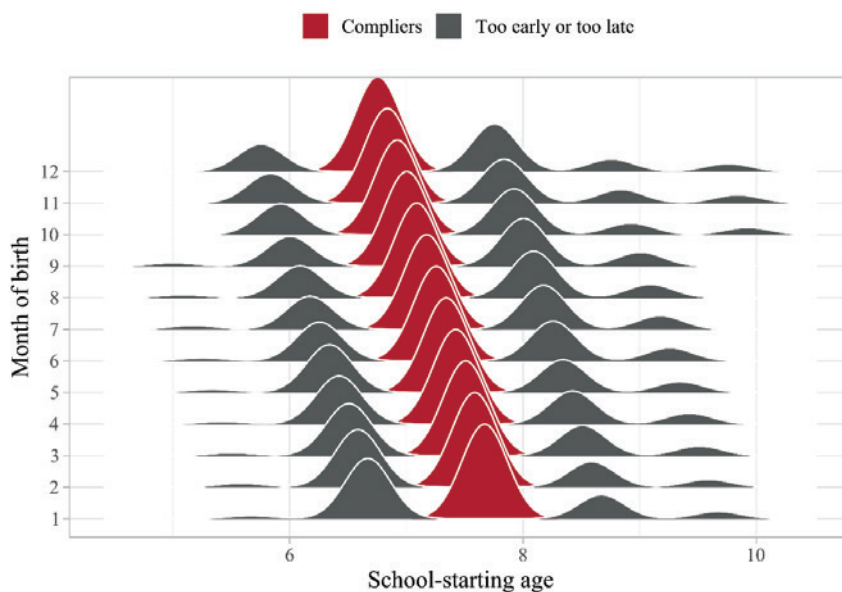
These three observations combined yield an expected pattern: mid-year born children are more likely to start school at the legislated age, children born at the beginning of the year (which are older in cohort) are marginally more likely to start school too young, while children born at the end of the year (which are younger in cohort) are marginally more likely to start school too old. All these conclusions also hold for the restricted sample presented in columns four to seven, and only the complier portion is slightly higher, as expected. The same pattern can be observed in Figure 3. Finally, in Figure 4, one could observe that the ratio of complier-defier population is relatively stable in the sample.

Table 1: Compliers and type of defiers of school-starting entry by month of birth

Month of birth Compliers		Too young	Too old	Compliers	Too young	Too old
January	0.581	0.236	0.184	0.625	0.253	0.122
February	0.601	0.216	0.183	0.648	0.231	0.121
March	0.608	0.189	0.203	0.657	0.202	0.140
April	0.637	0.158	0.204	0.687	0.170	0.142
May	0.653	0.146	0.201	0.711	0.158	0.131
June	0.679	0.113	0.208	0.731	0.121	0.148
July	0.689	0.095	0.216	0.746	0.102	0.151
August	0.683	0.090	0.227	0.745	0.097	0.158
September	0.697	0.082	0.221	0.755	0.088	0.157
October	0.673	0.095	0.233	0.719	0.100	0.181
November	0.679	0.092	0.229	0.720	0.095	0.184
December	0.676	0.086	0.238	0.723	0.088	0.188

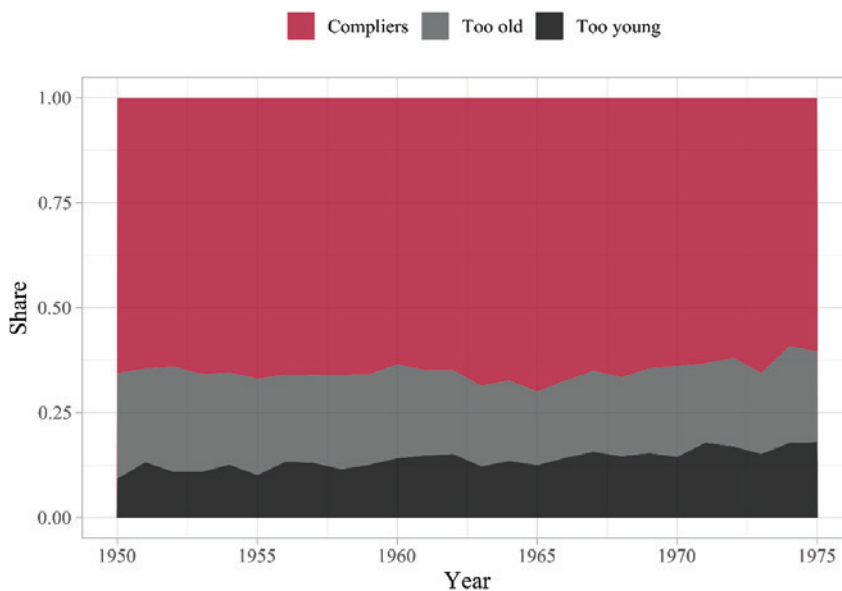
Source: Labour Force Surveys 2007-2018 and author's own calculations.

Figure 3: Histogram of school-starting age



Source: Labour Force Surveys 2007-2018 and author's own calculations.

Figure 4: Histogram of school-starting age



Source: Labour Force Surveys 2007-2018 and author's own calculations.

The most important challenge of the identification strategy is to control for potential unobserved heterogeneity that results in self-selection issues of the school-starting age, thus producing biased estimates. In addition, there might be other factors that affect the outcomes we are exploring, such as regional economic conditions, parental support, and job market changes. We, therefore, resorted to identification and methodological strategies from causal inference, which is an approach extensively used in applied economic literature, as can be seen, for example, in the works of Angrist and Pischke (2009, 2010) and Huntington-Klein (2021). In order to estimate the effect of relative age in the school on human capital formation, we used two empirical approaches, one based on the intent-to-treat OLS regression using end-year discontinuities, and one based on instrumental variables. If these empirical approaches are successful in identifying the causal effect, all of the concerns regarding unobserved heterogeneity and omitted variable bias are alleviated.

We started with an intent-to-treat approach where we compared educational and labour market outcomes of individuals born early and late in the year:

$$y_i = \alpha + \beta \times \text{end year}_i + \gamma' X_i + \eta_i + \epsilon_i \quad (1)$$

where:

- y_i is an outcome of interest for a person i , namely, years of completed education and an indicator of denoting if a person i is employed.
- end year_i is an indicator variable taking the value of 1 if the person i is born at the end of a calendar year – November or December, or both – and 0 otherwise, therefore the β is a parameter of interest.
- X_i is a vector of individual based covariates, namely gender and year of birth, which is important to ensure that we are comparing individuals within a cohort.
- η_i is the vector of LFS survey year dummies, which, among other things, controls for business cycle phase which is important when analysing labour market outcomes (employment).

We estimated Equation (1) separately for each outcome of interest and with different discontinuity samples. This estimation can be seen as an intent-to-treat as we do not use information on the actual (estimated) school start, just the legislated one. In a nutshell, this estimation approach is a discontinuity based one, as we use end-of year discontinuities to explore the effect of school-starting age. Note that the comparison is within the birth year, so we fundamentally compare years of completed education and employment status of individuals born early and late in the same year. This analysis is limited by observed endogenous non-

compliance as parents can delay or advance the school entry of their children, arguably based on ability. Therefore, we turned to instrumental variable (IV) approach, where an indicator of late year birth is an instrument for being young in cohort (again, note that I use estimated measure).

The IV equation we estimated is:

$$\begin{aligned} y_i &= \alpha_1 + \delta \times \text{start young}_i + \gamma_1' X_i + \eta_i + \varepsilon_i \\ \text{start young}_i &= \alpha_2 + \psi \times \text{end year}_i + \gamma_2' X_i + \eta_i + \varepsilon_i \end{aligned} \quad (2)$$

with the same variables as in Equation 1, with the addition of the δ which denotes an indicator if a person i was born late in the year and indeed started primary school when they should have, i.e., they were relatively young in cohort. The IV estimation within a LATE framework relies on the identifying assumptions introduced in the work by Angrist et al. (1996). While the first stage of IV holds – month of birth explains the age of school-start – as seen in the figures and table above, it is possible that the exogeneity assumption does not hold. Regardless of the estimated model – discontinuity based or instrumental variable based – forcing variable/instrument should be exogenous. In particular, the exogeneity assumption requires that the instrument, the month of birth, is random with respect to the potential outcomes. Figure 5 shows that, indeed, in the sample we did record more births in January than in December. We related this fact with the prevalence of home births for the cohorts in place, and given the eventful end of December in Croatia, arguably, some of these births were recorded in January. This implies that a portion of the individuals in the sample were actually older than what is recorded. In order to circumvent this potential source of bias, we extended our analysis by not only subsampling December-January births, but also the individuals born in October, November, February, and March.

Results

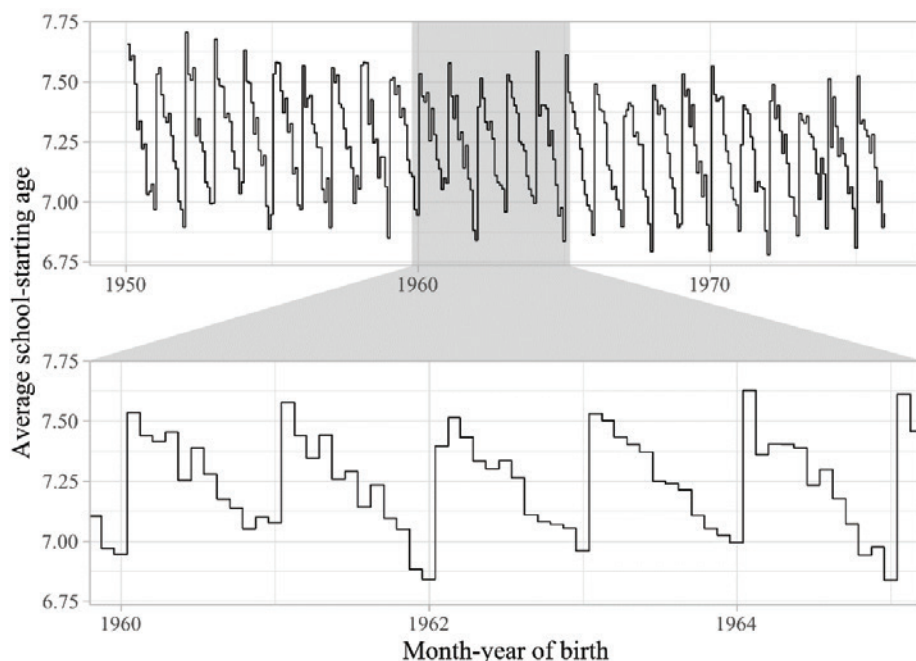
As already mentioned, in order to address the potential non-exogeneity of the month of birth, we used three subsamples for the two presented estimation models:

- Only people born in January and December, so January people should start school almost a year older than December people.
- People born in February and November.
- Only people born in the periods February-March and November-December, in order to avoid the January / December problems.

We presented the results separately for intent-to-treat estimates for educational and labour market outcomes – Table 2 and 3, respectively – as well as the instrumental variable estimates – Tables 4 and 5.

The results from Table 2 indicate that being younger in the cohort actually gives an educational premium. For example, comparing the same-cohort individuals born in January and December, we found that those who are relatively younger have 0.176 years of education more, which is also statistically distinguishable from zero at the 99-percent level – column (1). Circumventing the issue of non-randomness of a January birth, which we do by discarding January and December births, we found similar insights. In particular, comparing same-cohort individuals born in February and November, we found that the younger ones have 0.16 years of education more – column (2), while comparing individuals born in February and March to those born in October and November, we found that the effects still persist, albeit in a smaller magnitude (0.083 years of education more) and with less confidence from a statistical standpoint. Nonetheless, regardless of the composition of the sample, we found strong intent-to-treat evidence that being younger in cohort yields an educational premium of around 0.15 total years of education. Bearing in mind that the sample mean of years of education is 11.3, this absolute effect translates to an increase of approximately 1.3%.

Figure 5: Number of births by month-year in LFS



Source: Labour Force Surveys 2007-2018 and author's own calculations.

The results presented in Table 4, where we used instrumental variable approach to account for the endogeneity of school start, corroborate these base-line intent-to-treat results. For instance, when comparing individuals from the same cohort born in January and December, it is observed that those who are relatively younger have, on average, 0.236 additional years of education. This difference is statistically significant at the 99% confidence level, as indicated in column (1). Similar patterns emerge when we compare individuals born in February with those born in November, as the younger individuals attain, on average, 0.226 more years of education, as shown in column (2). Additionally, when comparing individuals born in February and March to those born in October and November, the educational advantage for younger individuals persists, although the effect size is reduced to 0.112 years of education. This latter comparison is characterized by lower statistical confidence.

Table 2: Intent-to-treat results on the total years of education

	Dependent variable: Total years of education		
	Jan vs. Dec	Feb vs. Nov	Feb-Mar vs. Oct-Nov
	(1)	(2)	(3)
Born at the end of the year	0.176***	0.160***	0.083*
	(0.058)	(0.052)	(0.043)
Year of birth fixed effects	Yes	Yes	Yes
Survey year fixed effects	Yes	Yes	Yes
Observations	25,617	23,874	50,436
Adjusted R ²	0.021	0.032	0.032

Notes: Each column represents the result of the estimation of Equation 1 using total years of education as a dependent variable, using different adjunct subsamples. The coefficient next to the term ‘Born at the end of the year’ is β as the causal parameter of interest from Equation 1. Standard errors in the parentheses are clustered at the year of birth level. Source: Labour Force Surveys 2007-2018 and author’s own calculations.

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table 3: Intent-to-treat results on the employed

	Dependent variable: Employed		
	Jan vs. Dec	Feb vs. Nov	Feb-Mar vs. Oct-Nov
	(1)	(2)	(3)
Born at the end of the year	0.023** (0.011)	0.033*** (0.010)	0.013** (0.006)
Year of birth fixed effects	Yes	Yes	Yes
Survey year fixed effects	Yes	Yes	Yes
Observations	25,617	23,874	50,436
Adjusted R ²	0.157	0.143	0.143

Notes: Each column represents the result of the estimation of Equation 1 using the employment indicator as a dependent variable, using different adjunct subsamples. The coefficient next to the term ‘Born at the end of the year’ is β as the causal parameter of interest from Equation 1. Standard errors in the parentheses are clustered at the year of birth level. Source: Labour Force Surveys 2007-2018 and author’s own calculations.

*p<0.1; **p<0.05; ***p<0.01.

Table 4: Instrumental variable results on the total years of education

	Dependent variable: Total years of education		
	Jan vs. Dec	Feb vs. Nov	Feb-Mar vs. Oct-Nov
	(1)	(2)	(3)
Young in cohort	0.264*** (0.088)	0.226*** (0.078)	0.112* (0.064)
Year of birth fixed effects	Yes	Yes	Yes
Survey fixed effects	Yes	Yes	Yes
Observations	25,552	23,808	50,279
Adjusted R ²	0.008	0.021	0.027

Notes: Each column represents the result of the estimation of Equation 2 using total years of education as a dependent variable, using different adjunct subsamples. The coefficient next to the term ‘Born at the end of the year’ is δ as the causal parameter of interest from Equation 2. Standard errors in the parentheses are clustered at the year of birth level. Source: Labour Force Surveys 2007-2018 and author’s own calculations.

*p<0.1; **p<0.05; ***p<0.01.

Table 5: *Instrumental variable results on the employed*

	Dependent variable: Employed		
	Jan vs. Dec	Feb vs. Nov	Feb-Mar vs. Oct-Nov
	(1)	(2)	(3)
Young in cohort	0.035**	0.046***	0.018*
	(0.016)	(0.015)	(0.009)
Year of birth fixed effects	Yes	Yes	Yes
Survey fixed effects	Yes	Yes	Yes
Observations	25,552	23,808	50,279
Adjusted R ²	0.156	0.140	0.142

Notes: Each column represents the result of the estimation of Equation 2 using the employment indicator as a dependent variable, using different adjunct subsamples. The coefficient next to the term ‘Born at the end of the year’ is δ as the causal parameter of interest from Equation 2. Standard errors in the parentheses are clustered at the year of birth level. Source: Labour Force Surveys 2007-2018 and author’s own calculations.

*p<0.1; **p<0.05; ***p<0.01.

Both intent-to-treat and instrumental variable estimations, therefore, produce synchronized results, as being younger in the cohort yields an educational benefit in terms of total years of education. While these effects are small in magnitude, they are novel to the literature as most of the papers document adverse or no educational effects of starting school younger, as can be seen, for example, in the works of Fertig and Kluve (2005), Kawaguchi (2011), Kaila (2017), Kawaguchi (2011), and Oosterbeek et al. (2021). However, our findings are in line with those by Dobkin and Ferreira (2010), who noted that although students who are the youngest in their school group generally perform worse academically, they tend to achieve slightly higher levels of education on average.

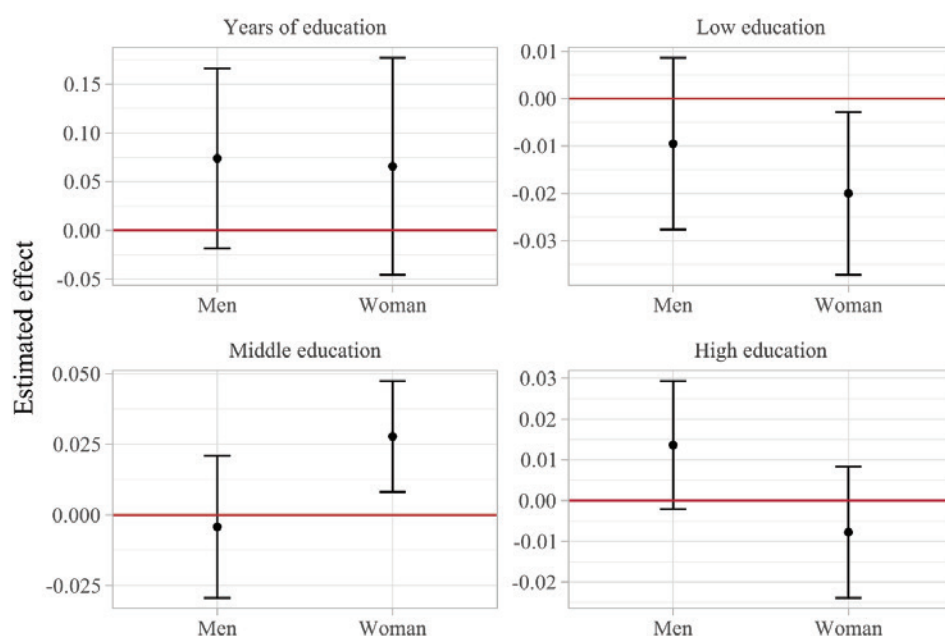
Tables 3 and 5 display the results within the same empirical framework, albeit for a different outcome: the indicator for being employed. Given that the outcome of interest is an indicator taking the value of 1 if the person is employed and 0 otherwise, the presented effects are in percentage points terms. The findings in Table 3 indicate that being relatively younger within a cohort provides an increased employment probability. Specifically, comparing individuals from the same cohort born in January and December reveals that those who are younger have an employment probability that is higher, on average, by 2.3 percentage points. This difference is statistically significant at the 95% confidence level, as shown in column (1). As in the estimates for total years

of education, to mitigate potential bias associated with the non-randomness of January births, we excluded individuals born in January and December from the analysis. Despite this adjustment, the results remained consistent. When comparing same-cohort individuals born in February with those born in November, we found that the younger individuals have a 3.3 percentage point higher probability of working, as presented in column (2). Furthermore, comparing individuals born in February and March to those born in October and November showed that the labour market advantage for younger individuals continues, although the effect size decreases to 1.3 percentage points, with lower statistical significance. Regardless of the specific sample used, there is strong intent-to-treat evidence suggesting that being younger within a cohort leads to an increased probability of being employed of approximately 2.3 percentage points. Given that the portion of employed people in the sample is around 60%, this absolute effect translates to roughly 3.8% of the sample mean. The results reported in Table 5, which utilise an instrumental variable approach to address the endogeneity of school starting age, further support these intent-to-treat findings. For example, the comparison of individuals born in January and December within the same cohort reveals that those who are relatively younger have, on average, a 3.5 percentage point higher probability of being employed, with this effect being statistically significant at the 95% confidence level, as shown in column (1). Similar results are found when comparing individuals born in February to those born in November, where the younger individuals have, on average, a 4.6 percentage points higher employment probability, as indicated in column (2). Lastly, comparing individuals born in February and March to those born in October and November continues to show a labour market premium advantage for the younger group, although the effect size is reduced to 1.8 percent points, with decreased statistical significance.

Finally, in order to unpack these effects in more detail, we also ran the intent-to-treat heterogeneous effects separately for different educational outcomes, separately for men and women, and the results are presented in Figure 6. While there is no sign of a strong gender gradient in the results as the estimated effects for most of the outcomes are comparable, one interesting insight emerged. If we inspect the estimates of those being younger in the cohort on having low (elementary school) and middle (high-school) education, we observe a statistically significant effect for women. In other words, relatively younger women in cohorts have a higher probability of achieving middle education, and a significantly lower probability of achieving low education. This pattern of educational attainment for younger women is, arguably, consistent

with the lower opportunity cost of additional schooling for this group compared to older cohort members. Younger women may face fewer economic pressures or familial responsibilities, allowing them more flexibility to pursue further education. Moreover, societal expectations and norms regarding education and career opportunities for women, especially for these cohorts, may be shifting over time, encouraging younger women to invest more in their education. This reduced opportunity cost, combined with potential long-term economic benefits of higher education, likely serves as a mechanism driving the observed effect.

Figure 6: *Heterogenous intent-to-treat estimates on education by gender*



Notes: Each panel represents the results of the estimation of Equation 1 for different outcome variables denoted in the panel title, separately by gender, using individuals born in October, November, February, and March. The first outcome is total years of education, while the next three are indicator variables of achieved specific educational levels. The points on the Y-axis show β coefficients, estimated, while the bars indicate a 90% confidence interval using standard errors clustered at the year of birth level. Source: Ministry of Finance, Tax Administration, and author's own calculations.

CONCLUSIONS

This study investigates the impact of school starting age on educational performance and subsequent labour market outcomes in Croatia, with a particular focus on how these factors contribute to human capital accumulation. Understanding the optimal age for school entry is crucial, as human capital – skills, knowledge, and experience – plays a fundamental role in economic growth. By examining whether starting school at a younger or older age leads to better academic achievements and more favourable labour market outcomes, this study seeks to provide insights into how educational policies can be aligned to maximize human capital development. Using school-entry rules and month-of-birth discontinuities to obtain exogenous variation in school starting age, this research analyses cohorts born between 1950 and 1975, offering a detailed perspective on the long-term effects of age at school entry. The findings suggest that being younger within a school cohort offers a slight educational premium, as younger students tend to have slightly more years of education compared to their older peers, especially women. This, we argue, is driven by the lower opportunity cost of continuing education for younger students. This contrasts with much of the existing literature, which often reports that older school starters perform better academically due to greater maturity and readiness for school. However, similar to Dobkin and Ferreira's (2009) findings, this study shows that younger students may ultimately achieve higher educational levels, despite the initial academic challenges. With regard to the labour market outcomes, the results indicate that relatively younger students within a cohort have a higher probability of being employed during the survey timespan, which is possibly a ramification of educational premium and/or earlier labour market entry. The pitfalls of this research are also a guideline for future research within this framework. As Oosterbeek et al. (2021) note, the totality of these effects is convoluted within different mechanisms: school starting age, relative age in class, and age-at-test effects. Therefore, in order to corroborate our conclusions, a more detailed empirical approach which circumvents these results is needed. In addition, future research should continue to explore these dynamics in different settings in order to better understand how school starting age policies can be optimised to support both educational and economic agendas.

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ENERGY and ENVIRONMENTAL ECONOMICS

IMPACT OF ENERGY SOURCE COMPOSITION ON CO₂ EMISSIONS: AN ANALYSIS USING GDP AND ELECTRICITY PRODUCTION

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This empirical study explores the relationship between carbon dioxide emissions and key economic and energy production factors, specifically focusing on GDP per capita (adjusted for purchasing power parity) and electricity production from various energy sources, including nuclear, fossil fuels, and renewables (hydro, geothermal, solar, wind, and other renewables). The study assesses how these factors influence carbon emissions by using yearly panel data for 47 countries, the longest period spanning from 2010 to 2023. A fixed effects regression model with Driscoll and Kraay standard errors was applied to account for autocorrelation and heteroskedasticity, common issues in panel data analysis. Findings indicate a significant inverse relationship between carbon emissions and both GDP per capita (in terms of purchasing power parity) and per capita renewable energy production. This suggests that higher levels of economic development and an increased share of renewable energy in the energy mix are linked to lower emissions. In contrast, the study identifies a positive and statistically significant association between carbon dioxide emissions and electricity generation from nuclear energy and combustible fuels, highlighting the differing environmental impacts of various energy sources. The results of the study underscore the complexity of the relationship between energy production, economic growth, and environmental

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sustainability. While economic development and the use of renewable energy sources are associated with reduced carbon emissions, the reliance on nuclear and fossil fuels appears to exacerbate emissions despite their role in energy security. This paper contributes to the broader discourse on sustainable energy policy by offering empirical evidence that both economic growth (as measured by purchasing power parity) and renewable energy adoption can help mitigate carbon emissions. At the same time, it emphasizes the need for balanced energy policies that consider the trade-offs between energy security, economic development, and environmental impact, offering valuable insights for policymakers seeking to promote sustainable energy transitions.

Keywords: *CO₂ emissions, developed countries, economic development, electricity production.*

JEL classification: *C23, Q53, Q54.*

INTRODUCTION

Balancing economic growth with environmental sustainability is an ongoing economic policy concern. As economies worldwide focus on reducing carbon dioxide emissions, it is important to explore how different energy sources and economic factors contribute to emission levels. Carbon dioxide emissions are a major driver of global warming; thus, it is essential to identify and measure the factors that impact emission levels. The energy sources used to produce electricity, whether from renewables, nuclear energy or combustible fuels, have differing effects on CO₂ emissions (IEA, 2024).

Fossil fuels have played a significant role in economic development since the Industrial Revolution. They have powered electricity production, transportation, and industries. As a result, economic growth has usually led to higher CO₂ emissions. However, this trend is changing. Improvements in energy efficiency mean that less energy is needed for economic growth. Additionally, the use of clean energy sources has increased. In many developed countries, CO₂ emissions peaked in 2007 and have since decreased. For example, the EU's economy has grown by 66% since 1990, while CO₂ emissions have dropped by 30%. Other advanced economies have followed similar patterns. Many advanced economies, like the U.S. and the EU, have decoupled GDP growth from CO₂ emissions, showing emissions reduction alongside economic growth. These trends are also observed in emerging economies, such as China

and India, although CO₂ emissions are still rising. However, some regions like Southeast Asia and the Middle East continue to see both emissions and economic growth increase together. (IEA, 2024).

The current global energy situation is still unsettled due to high fossil fuel prices and ongoing wars in Ukraine and the Middle East, but clean energy is making progress. Investments in solar power and electric vehicles (EVs) are growing rapidly. In 2023, one in five cars sold was electric. Although achieving net-zero emissions remains difficult, the shift to cleaner energy is becoming increasingly important (IEA, 2024). “Net zero emissions” means balancing the amount of greenhouse gases produced with the amount removed from the atmosphere. Imagine a set of scales: producing greenhouse gases makes one side heavier, and the goal is to make the scales balance, so no more greenhouse gases are added to the atmosphere than are removed. In order to prevent a climate disaster, greenhouse gas emissions must be reduced as much as possible. This means aiming for real zero emissions and only using carbon offsetting when necessary. To achieve this, fossil fuels like coal, oil, and gas must be quickly phased out, and renewable energy should replace them in all sectors of the economy (Climate Council, 2023). Globally, fossil fuel investments are slowing down, signalling a transition toward cleaner energy, although more work is needed to meet the climate goals. Achieving net zero by 2050 is important for limiting global warming to 1.5 °C and preventing the negative effects of climate change (IPCC, 2018).

This study aims to examine how GDP per capita (adjusted for purchasing power parity) and different energy sources – nuclear, renewable (including solar, wind, hydro, and geothermal), and combustible fuels – affect CO₂ emissions. The research includes data from 47 countries over a period from 2010 to 2023, applying a fixed effects panel regression model in order to ensure robust results. By addressing the interaction between economic development and energy production, this study seeks to offer new insights into how countries can balance economic growth with sustainability.

LITERATURE REVIEW

The relationship between economic growth and environmental impact has been widely studied in literature. According to the Environmental Kuznets Curve (EKC), as countries develop, pollution initially increases, but after reaching a certain level of wealth, it begins to decrease. In developed economies, this can be observed as the shift toward cleaner technologies and renew-

able energy (Grossman & Krueger, 1995). Stern (2004) critically examines the Environmental Kuznets Curve (EKC), arguing that developing countries are addressing environmental issues more effectively than expected. Saidi and Hammami (2015) found a statistically significant negative impact of GDP per capita on CO₂ emissions, suggesting that economic growth leads to emissions reduction.

However, combustible fuels remain the primary driver of emissions, especially in developing regions where energy transitions to cleaner sources are still underway. The elasticity of CO₂ emissions in response to fossil fuel use is often positive, as increased reliance on fossil fuels typically leads to higher emissions (Diallo & Quoba, 2023). Wang et al. (2016) have shown that countries with higher electricity production from fossil fuels experience higher per capita CO₂ emissions.

Regarding nuclear energy, it has a relatively small, but positive role in reducing emissions. Nuclear power produces significant amounts of energy without directly emitting CO₂, although it is not without its environmental challenges, such as radioactive waste disposal and the risk of accidents (York, 2012).

Renewable energy sources, such as solar, wind, hydro and geothermal, are increasingly viewed as key solutions to mitigating climate change. These sources are carbon-neutral in terms of their direct emissions, and contribute significantly to reducing the reliance on fossil fuels. Lin and Li (2019) observed that increased use of renewable energy is strongly correlated with lower CO₂ emissions, especially as countries shift away from coal and oil. Lin and Li (2019) found that electricity plays a crucial role in modern energy services and climate mitigation by substituting fossil fuels, with clean energy sources significantly reducing carbon emissions. Using data from 114 countries (2000-2014), they outline that higher electricity use, especially from clean sources, leads to lower carbon emission growth, while factors like population, economic growth, urbanization, and industrialization contribute to higher emissions.

Furthermore, Diallo and Quoba (2023) demonstrated that renewable energy investments have a positive effect on economic growth, particularly in sub-Saharan Africa, finding that renewable energy positively contributes to growth.

In countries such as China and India, rapid industrial growth and urbanization have led to higher energy use, much of it originating from fossil fuels. A study by Wang et al. (2016) found that in China, energy consumption drives CO₂ emissions. This means that while economic growth leads to higher emissions, China's reliance on coal for energy remains a major obstacle to reducing emissions.

DATA AND METHODS

Carbon dioxide (CO_2) is a compound consisting of one carbon atom and two oxygen atoms. It is naturally produced through processes such as volcanic activity, wildfires and biological respiration. Additionally, human activities, particularly the combustion of fossil fuels for energy production and transportation, contribute significantly to the release of CO_2 into the atmosphere. As a greenhouse gas, CO_2 is integral to the greenhouse effect, wherein it absorbs solar radiation and traps heat within the Earth's atmosphere, thereby sustaining a climate conducive to life. While CO_2 is not the most potent greenhouse gas, it is the most influential in driving the greenhouse effect due to its high concentration, accounting for nearly two-thirds of global greenhouse gas emissions. Consequently, this paper will primarily examine the annual CO_2 emissions of developed nations, focusing on this key factor. CO_2 emissions are the primary variable for analysis in this study, expressed in metric tons per capita, with data obtained from the World Bank database (World Bank, 2024a).

The progression of CO_2 emissions in various countries will be analyzed, considering each country's economic development level and its electricity production from different sources. Economic development will be measured using gross domestic product (GDP). Since countries vary in population size, both GDP and CO_2 emissions will be assessed on a per capita basis to allow for comparability across countries. Additionally, to further enhance comparability, GDP per capita will be expressed in current international dollars, adjusted by the purchasing power parity (PPP) conversion factor. The data for this variable were sourced from the World Bank database (World Bank, 2024b).

Electricity production will be analyzed as net electricity production, both in total and by specific sources used for generation. Three main sources will be examined: nuclear, combustible fuels, and renewables (including hydro, geothermal, solar, and wind). Together, these sources account for total electricity production. All net electricity production variables are measured in gigawatt hours (GWh) and on a per capita basis. The data source for these variables is the International Energy Agency (IEA). It should be noted that the original data for net electricity production were provided on a monthly basis (International Energy Agency, 2024). However, in order to minimize seasonal effects in electricity production, the data will be aggregated and analyzed on an annual basis. The complete list of observed variables is provided in Table 1.

Table 1: List of observed variables with codes and sources

Variable code	Variable	Source
CO2	CO ₂ emissions (metric tons per capita)	World Bank, 2024a
GDPPC	GDP per capita, PPP (current international \$)	World Bank, 2024b
NUCLEAREP	Net Electricity Production - Nuclear, GWh, per capita	International Energy Agency, 2024
FUELEP	Net Electricity Production - Total Combustible Fuels, GWh, per capita	International Energy Agency, 2024
RENEWABLESEP	Net Electricity Production - Total Renewables (Hydro, Geo, Solar, Wind, Other), GWh, per capita	International Energy Agency, 2024
TOTALEP	Net Electricity Production - Total, GWh, per capita	International Energy Agency, 2024

The analysis will include a total of 47 countries – namely Argentina, Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, China, Colombia, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, India, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, Malta, Mexico, the Netherlands, New Zealand, North Macedonia, Norway, Poland, Portugal, the Republic of Korea, Romania, Serbia, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Türkiye, the United Kingdom, and the United States of America. Yearly data for the period from 2010 to 2023 will be analyzed. Unfortunately, data were not available for all countries across the entire observed period. Therefore, certain adjustments will be made during the analysis to address this issue. The number of available data points by variable and year is presented in Table 2, whereas the number of available data points by variable and countries is presented in Appendix in Table A1.

Table 2: Number of available data points by variables and years observed

Year	CO2	GDPPC	NUCLEAREP	FUELEP	RENEWABLESEP	TOTALEP
2010	47	47	35	35	35	35
2011	47	47	35	35	35	35
2012	47	47	35	35	35	35
2013	47	47	35	35	35	35
2014	47	47	35	36	36	36
2015	47	47	47	47	47	47
2016	47	47	47	47	47	47
2017	47	47	47	47	47	47
2018	47	47	47	47	47	47
2019	47	47	47	47	47	47
2020	47	47	47	47	47	47
2021	0	47	47	47	47	47
2022	0	47	47	47	47	47
2023	0	47	47	47	47	47

Based on the most recent data, the observed countries contributed 72.63% of the total global CO₂ emissions in 2022 (27,976.85 megatons of carbon dioxide equivalent) (World Bank, 2025a). These countries accounted for 83.84% of the total global gross domestic product (89.02 trillion US\$) in 2023 (World Bank, 2025b) and 56.02% of the world population (4.52 billion) in 2023 (World Bank, 2025c).

Figure 1: Development of total CO₂ emissions and total GDP in the observed countries in the period from 2010 to 2023, 2010=100

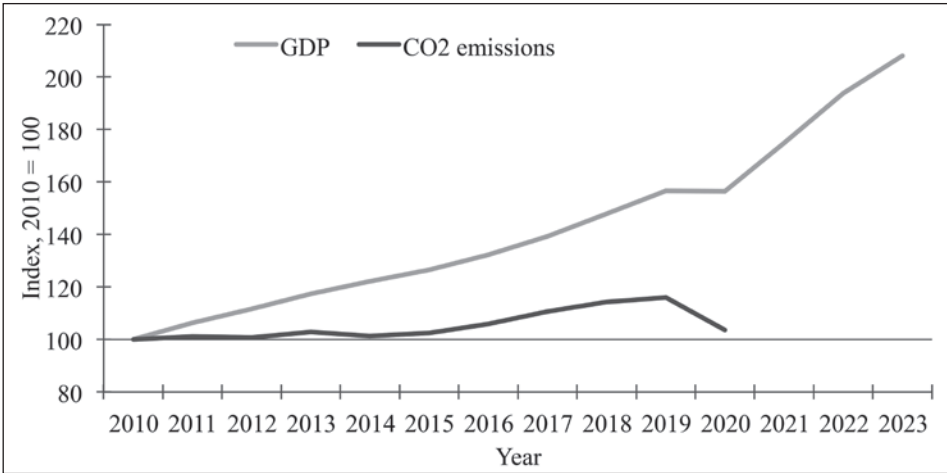
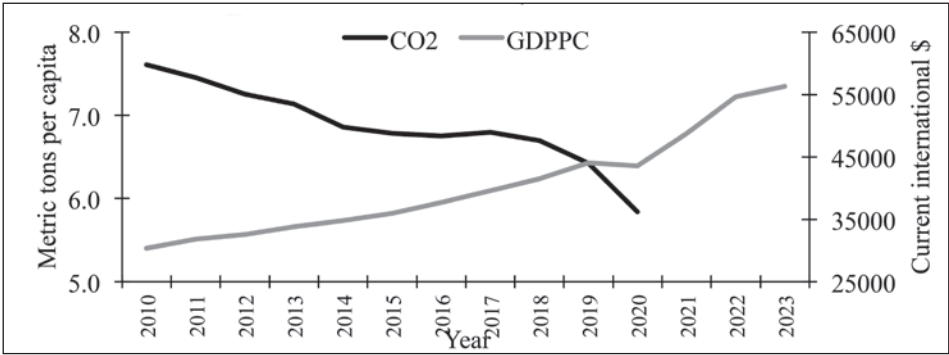


Figure 1 illustrates the decoupling of total CO₂ emissions from total GDP in the observed countries during the period from 2010 to 2023. While total GDP has increased at a significantly higher rate than total CO₂ emissions, the data suggest that CO₂ emissions have been declining since 2019, further widening the gap between GDP and emissions. However, recent data are not available to confirm if this trend has continued.

Figure 2: Development of average CO₂ emissions and average GDP per capita in the observed countries in the period from 2010 to 2023



According to Figure 2, average CO₂ emissions in the 47 observed countries decreased from 7.61 metric tons per capita in 2010 to 5.84 metric tons per capita in 2020. Unfortunately, data on CO₂ emissions are not available for periods later than 2020. In contrast, the average GDP per capita in the observed countries, as shown in Figure 2, clearly increased during the same period. From \$30,370.68 in 2010, the average GDP per capita in the observed countries grew to \$56,335.16 in 2023. This suggests that CO₂ emissions and GDP per capita have developed in opposite directions.

Figure 3 shows the average net electricity production values in the observed countries. According to Figure 3, average net electricity production from nuclear sources (NUCLEAREP) has remained constant at approximately 0.010 GWh per capita throughout the observed period. In contrast, average net electricity production from combustible fuels (FUELEP) appears to be decreasing, from 0.0038 GWh per capita in 2010 to 0.0023 GWh per capita in 2023. Since 2015, the average net electricity production from renewable sources (RENEWABLESEP) and total electricity production (TOTALEP) have remained at similar levels in the observed countries.

Figure 3: Development of average net electricity production variables in the observed countries in the period from 2010 to 2023

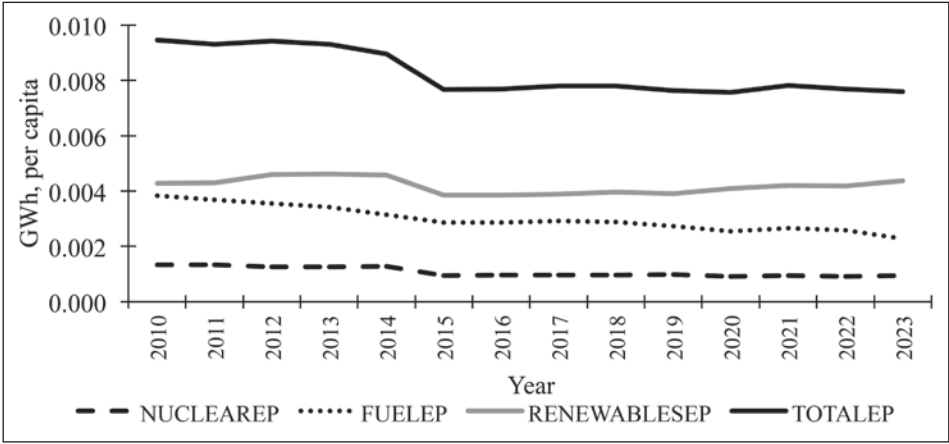
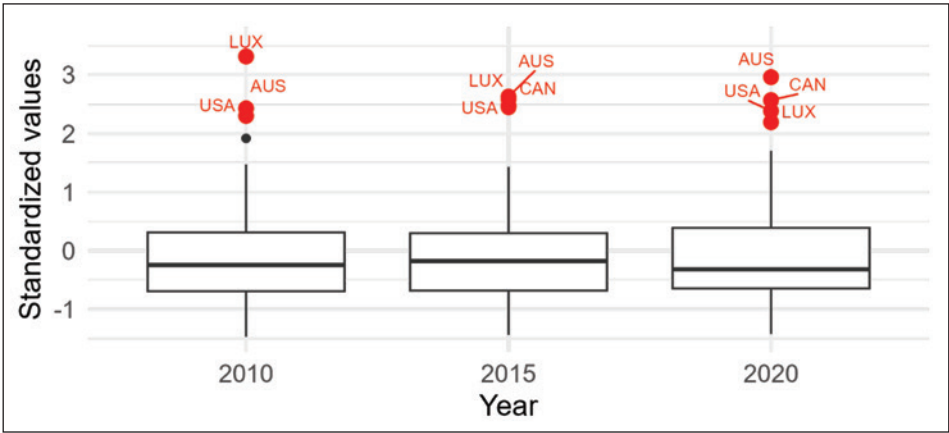


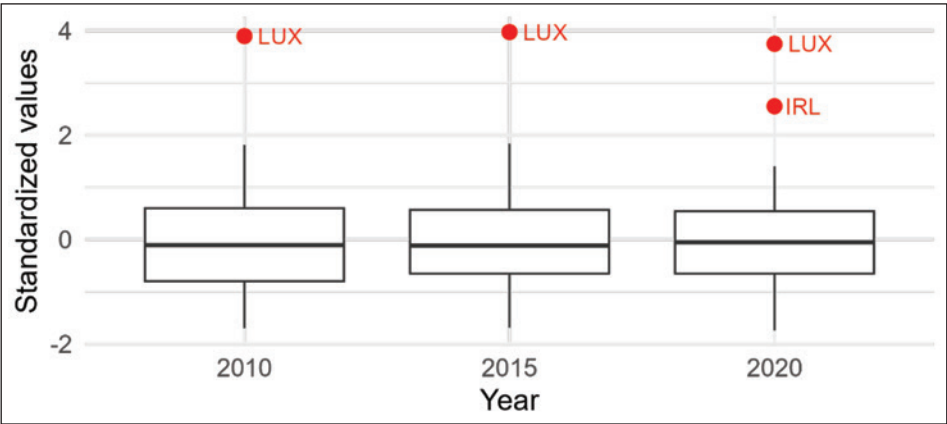
Figure 4 shows box plot diagrams for the variable of CO₂ emissions (metric tons per capita) in the observed countries for three selected years: 2010, 2015 and 2020. The data were first standardized and then plotted. Data points that deviate more than 2 standard deviations from the average are highlighted in Figure 4. Obviously, four countries stand out due to their high levels of CO₂ emissions: Australia, Canada, Luxembourg and the United States of America.

Figure 4: Box plot diagrams for CO₂ emissions (metric tons per capita) in the observed countries for 2010, 2015, and 2020



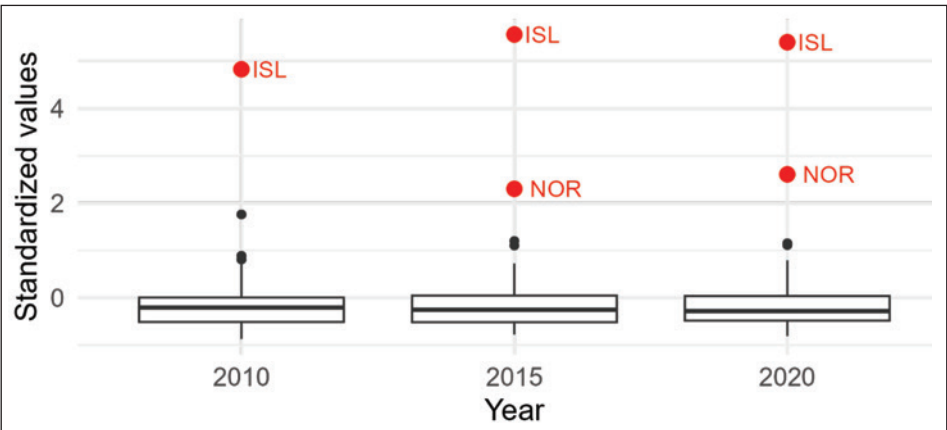
If the economic development level of the observed countries is compared based on the variable GDP per capita, Figure 5 clearly shows that Luxembourg stands out compared to the other countries. In 2020, Ireland also had a very high GDP per capita compared to the average of the observed countries.

Figure 5: Box plot diagrams for GDP per capita, PPP (current international \$) in the observed countries for 2010, 2015, and 2020



According to the total net electricity production measured in GWh per capita, Iceland has much higher levels of production than the other countries. In addition, Figure 6 shows that Norway stands out with higher total net electricity production measured in GWh per capita compared to the other countries.

Figure 6: Box plot diagrams for total net electricity production (GWh per capita) in the observed countries for 2010, 2015, and 2020



As a part of our empirical exercise, we have developed an empirical model in which the CO₂ emissions (metric tons per capita) serve as the dependent variable. The model is a fixed effects model (within) regression, utilizing Driscoll and Kraay standard errors, which are appropriately adjusted for cross-sectional dependence, as observed in our analysis.

ANALYSIS AND DISCUSSION

Compared to purely cross-sectional data, panel data is advantageous because it typically provides more information, which leads to greater precision in estimation. However, the actual informational value of macro panels is often overstated, as such data is prone to various cross-sectional and temporal dependencies. As a result, failing to account for potential correlations in regression disturbances over time and across subjects can result in biased statistical inferences.

We conducted a Modified Wald test for group-wise heteroscedasticity in the fixed effect regression model to test the null hypothesis of homoskedasticity (constant variance), $H_0: \sigma_i^2 = \sigma^2$ for all i . Since the null hypothesis was rejected ($\chi^2(24) = 1660.91$, Prob. < 0.0001), we concluded that heteroskedasticity is present in our baseline fixed effects model.

Recognizing that cross-sectional dependence is more of an issue in macro panels compared to micro panels, we applied the Pesaran CD (cross-sectional dependence) test to determine whether the residuals are correlated across entities (countries). Cross-sectional dependence can introduce bias in test results, known as contemporaneous correlation. The null hypothesis of no residual correlation was rejected (Pesaran's test of cross-sectional independence = 11.858, Prob. < 0.0001, Average absolute value of the off-diagonal elements = 0.538), indicating the presence of cross-sectional dependence.

Given the issues of heteroskedasticity and cross-sectional dependence, our estimation approach involved using the fixed effects (within) regression model with Driscoll and Kraay standard errors. Unlike standard methods, the Driscoll and Kraay estimator accounts for cross-sectional dependence, providing consistent and robust standard error estimates (Driscoll and Kraay, 1998). These standard errors are not only heteroskedasticity-consistent, but also robust to a wide range of cross-sectional and temporal dependencies.

For the purpose of the empirical analysis, we have left out the variable Net Electricity Production - Total, GWh, per capita (TOTALEP), so the baseline empirical model is the following:

$$\ln CO2_{it} = \beta_0 + \beta_1 \ln GDP_{it} + \beta_2 \ln NUCLEAREP_{it} + \beta_3 \ln FUELEP_{it} + \beta_4 \ln RENEWABLESEP_{it} + \varepsilon_{it} \quad (1)$$

where: i is country and t is the time, $\ln CO2_{it}$ is the natural logarithm of CO₂ emissions (metric tons per capita), $\ln GDP_{it}$ is the natural logarithm of GDP per capita, PPP (current international \$), $\ln NUCLEAREP_{it}$ denotes the natural logarithm of Net Electricity Production - Nuclear, GWh, per capita, $\ln FUELEP_{it}$ denotes natural logarithm of Net Electricity Production - Total Combustible Fuels, GWh, per capita, and $\ln RENEWABLESEP_{it}$ denotes natural logarithm of Net Electricity Production - Total Renewables (Hydro, Geo, Solar, Wind, Other), GWh, per capita. Finally, ε_{it} is a random error term.

The results of the fixed-effects regressions with Driscoll-Kraay standard errors are presented in Table 3. The estimated models seem to fit the data rather well, as indicated by an R-squared of 0.3249 and an F-statistic of $F(4, 23) = 87.59$, with a p-value < 0.0001 .

Table 3: Estimation results of Driscoll-Kraay standard errors regression

	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
lnGDP	-0.1451	0.0238	-6.09	0.000	-0.1944	-0.0958
lnNUCLEAREP	0.0202	0.0162	1.25	0.225	-0.0132	0.0536
lnFUELEP	0.1608	0.0615	2.61	0.016	0.0335	0.2882
lnRENEWABLESEP	-0.1210	0.0296	-4.08	0.000	-0.1824	-0.0597
Constant	3.7292	0.6049	6.17	0.000	2.4779	4.9805

Method: Fixed-effects regression, Number of obs = 233, Number of groups = 24

The results presented in Table 3 show that the impact of Net Electricity Production - Nuclear, GWh, per capita to CO₂ emissions is not statistically significant, despite having a positive coefficient. In contrast, the impact of GDP per capita, PPP (current international \$) to CO₂ emissions is statistically significant and negative, with a coefficient of -0.15. The impact of Net Electricity Production - Total Combustible Fuels, GWh, per capita to CO₂ emissions is also statistically significant and positive, with the largest coefficient of 0.16. Finally, the impact of Net Electricity Production - Total Renewables (Hydro, Geo, Solar, Wind, Other), GWh, per capita to CO₂ emissions is statistically significant and negative.

CONCLUSION

This study examined the relationship between carbon dioxide (CO₂) emissions, economic development, and energy production sources in 47 countries in the period from 2010 to 2023. Using a fixed-effects panel regression model with Driscoll and Kraay standard errors, the analysis revealed that GDP per capita (adjusted for purchasing power parity) has a statistically significant negative effect on CO₂ emissions, indicating that higher economic development is linked to lower emissions. The study also shows that per capita renewable energy production significantly reduces CO₂ emissions, suggesting that increasing the use of renewable energy can help decrease emissions.

In contrast, electricity generation from fossil fuels was found to have a statistically significant positive effect on CO₂ emissions, underscoring the environmental cost of fossil fuel dependency. Nuclear energy, however, did not exhibit a statistically significant impact on emissions, implying that its role in reducing CO₂ emissions is more complex and warrants further investigation.

In conclusion, the findings highlight that both economic growth and a shift toward renewable energy sources can help reduce CO₂ emissions, while continued reliance on fossil fuels contributes to higher emissions. The growing global investment in renewable energy marks progress toward cleaner energy systems. Policymakers play a critical role in facilitating this transition and should focus on policies that promote clean energy and energy efficiency to support sustainable development and meet climate goals.

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APPENDIX

Table A1: Number of available data points by variables and countries observed

Country	CO2	GDPPC	NUCLEAREP	FU-ELEP	RENEWAB-LESEP	TOTALEP
Argentina	11	14	9	9	9	9
Australia	11	14	14	14	14	14
Austria	11	14	14	14	14	14
Belgium	11	14	14	14	14	14
Brazil	11	14	9	9	9	9
Bulgaria	11	14	9	9	9	9
Canada	11	14	14	14	14	14
Chile	11	14	14	14	14	14
China	11	14	9	9	9	9
Colombia	11	14	10	10	10	10
Croatia	11	14	9	9	9	9
Cyprus	11	14	9	9	9	9
Czechia	11	14	14	14	14	14
Denmark	11	14	14	14	14	14
Estonia	11	14	14	14	14	14
Finland	11	14	14	14	14	14
France	11	14	14	14	14	14
Germany	11	14	14	14	14	14
Greece	11	14	14	14	14	14
Hungary	11	14	14	14	14	14
Iceland	11	14	14	14	14	14
India	11	14	9	9	9	9
Ireland	11	14	14	14	14	14
Italy	11	14	14	14	14	14
Japan	11	14	13	14	14	14
Latvia	11	14	14	14	14	14
Lithuania	11	14	14	14	14	14
Luxembourg	11	14	14	14	14	14
Malta	11	14	9	9	9	9
Mexico	11	14	14	14	14	14
Netherlands	11	14	14	14	14	14
New Zealand	11	14	14	14	14	14
North Macedonia	11	14	9	9	9	9
Norway	11	14	14	14	14	14
Poland	11	14	14	14	14	14
Portugal	11	14	14	14	14	14

Country	CO2	GDPPC	NUCLEAREP	FU-ELEP	RENEWAB-LESEP	TOTALEP
Republic of Korea	11	14	14	14	14	14
Romania	11	14	9	9	9	9
Serbia	11	14	9	9	9	9
Slovak Republic	11	14	14	14	14	14
Slovenia	11	14	14	14	14	14
Spain	11	14	14	14	14	14
Sweden	11	14	14	14	14	14
Switzerland	11	14	14	14	14	14
Türkiye	11	14	14	14	14	14
United Kingdom	11	14	14	14	14	14
United States of America	11	14	14	14	14	14

THE IMPORTANCE OF EDUCATING HOUSEHOLDS ON ENERGY SAVINGS FOR REDUCING ENERGY CONSUMPTION AND POLLUTION

Amra GADŽO *, **Amra BABAJIĆ****, **Amra NUHANović*****

This study explores the impact of educating households on energy savings and its subsequent effect on reducing energy consumption and pollution. The research was conducted on a sample of 10,044 household owners in the Tuzla Canton of the Federation of Bosnia and Herzegovina. During the first round of household visits, data on individual household electricity consumption for the past twelve months were collected, education on possible energy savings in households was conducted, and four standard light bulbs were replaced with four LED light bulbs. After one year, a second round of data collection on household electricity consumption for the period of twelve months was conducted. The paper presents the comparative indicators of electricity consumption before and after education, the achieved savings in consumption, and a calculation of reduced harmful emissions into the air.

The research results showed that educating household owners about possible energy savings resulted in an increase in their efforts to achieve energy savings. The value of the achieved energy savings amounts to 4.47% in percentage terms, i.e. 1,962,676.50 kWh in absolute terms, and the recalculated value of savings in EUR amounts to 166,079, while the value of reduced air emissions amounts to 2,345,398.42 kg CO₂. The highest energy savings were achieved in the municipality of Kalesija at 8.76%, while the lowest were in the city of Živinice at 2.64%.

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The results of this study will contribute to the literature gap with regard to understanding the importance of educating the population, their behavioural characteristics, potential energy savings, and the cost-benefit analysis of such energy-saving projects.

Keywords: *education of household owners, energy savings, reduction of energy consumption, reduction of air pollution.*

JEL classification: *P18, P28, P36, M40.*

INTRODUCTION

We are witnessing accelerated changes all around us. Climate change represents one of the countless challenges posed by human activity to the environment, and will probably dominate international development and sustainable perspectives for a long time to come. Various economic activities affect these processes, mostly in the field of energy, agriculture, industry, waste management, etc. Nevertheless, the production and use of energy represents the biggest challenge for the quality of the environment. This raises a number of questions, primarily regarding the so-called “greenhouse effect” and in connection with this, the possibility of global warming, which results in an increase in global temperature, a rise in the sea level, changes in the water regime, impact on ecosystems, agriculture, forest fund, etc. Thermal power plants are the largest contributors to the emission of carbon dioxide. According to some estimates, the human population will number around 9 billion people by 2050, all of whom will need to be provided with food, while the number of inhabitants in cities will increase by 2 billion, and the entire human population will need access to energy while reducing greenhouse gas emissions and ensuring a sustainable future. At the same time, if the problem of global warming is not solved, floods and droughts will intensify, sea levels will rise, water and food security will be more threatened, and the number of natural disasters will increase, which, according to the World Bank’s estimates, will “suppress about 100 million people into poverty in the next 15 years”. (The World Bank, 2020.)

The most comprehensive international agreement on reducing greenhouse gas emissions was verified in Paris at the end of 2015. At that time, the representatives of 196 countries agreed to take all the necessary measures to keep the level of global temperature increase below 2°C by the end of the 21st century, aiming for an increase of 1.5°C. Scientists estimate that the 1.5°C warm-

ing option is much safer for our civilization than the 2°C warming option, and that humanity is on its way to a catastrophic 3°C warming.

There is a consensus among scientists that global warming of dramatic proportions will occur if forces are not joined at the global level to prevent it, that is, if adequate mechanisms of direct investment for this purpose are not implemented. Regardless of the fact that many countries have already defined different strategies and action plans for mitigating climate change, in which cost-effective measures to reduce emissions are proposed (that is, with which it is possible to keep emissions below the level established by the Kyoto Protocol), until their practical implementation, it is mostly hard to achieve. In the next decades, a significant growth in world energy production, i.e. consumption of all energy sources, is forecast.

The world is rapidly switching to the use of renewable energy sources, and is discarding old technologies in the production of electricity. However, less developed countries are still dependent on traditional producers, such as solid fuel thermal power plants, and face numerous development and environmental problems due to this production. Electricity generation has a significant impact on the environment, particularly through the emissions of harmful gases such as CO₂ and SO₂ (Majumder, 2023; Kaldellis et al., 2004). Coal-fired power plants that use high-sulphur coal, such as the Ugljevik Power Plant, are major polluters (S. Stajić & Čepić, 2020). An analysis of the Kuznets environmental curve in transitional countries shows that in some states, there is a positive correlation between energy consumption and CO₂ emissions, indicating a need for policies aimed at improving energy efficiency (Pejović, 2022). Although highly developed countries are the biggest polluters of the environment, according to World Bank estimates, climate change will cause the most damage to underdeveloped and developing countries in the future.

One of the ways to reduce energy consumption is to influence consumer behaviour in order to achieve savings in energy consumption. This paper is, therefore, an attempt to determine to what extent the education of household owners can influence the reduction of electricity consumption, and what the potential savings are in terms of energy consumption, household income and the reduction of CO₂ emissions into the air, which such education projects could achieve in Bosnia and Herzegovina.

Bosnia and Herzegovina is an upper-middle income country, facing many social, political and economic issues (such as low productivity, migrations of working population, high unemployment, low investments, corruption and low transparency, etc.). It was interesting to investigate the impact of education on the reduction of electricity consumption in the larger entity of the state - the

Federation of Bosnia and Herzegovina, especially in light of recent increases in electricity prices in this area (in August 2024, the price of electricity for households increased by 23%).

The first part of the paper includes a literature review in the field of education and savings in electricity consumption. The second part of the paper refers to the detailed Research Methodology and Data Sources, while the third part of the paper presents Research Results and Discussion, after which the main conclusions of the research are presented.

LITERATURE REVIEW

There is a growing scientific research fund highlighting the education and energy consumption nexus. Many authors have shown that education has a positive impact on the reduction of electricity consumption, while on the other hand, there are studies that show that education has no effect on the reduction of electricity consumption. Inglesi-Lotz and Morales (2017) analysed the causal and empirical relationship between primary energy consumption and education for a group of developed and developing countries, as well as an aggregate panel of these groups for the period from 1980 to 2013. The results confirm a unidirectional relationship from education to energy consumption. Nahmens and Joukar (2014) investigated how education changes the behaviour of low-income consumers who most often live in energy-inefficient households. They came to the conclusion that such households need effective training programs that will lead to the adoption of new energy-efficient habits which will ultimately lead to a reduction in electricity consumption, where it is very important to use effective educational strategies (demonstration techniques - which take into account the unique socioeconomics and demographics of low-income residents). Effective educational strategies, like practical demonstrations, were highlighted as essential for sustainable behaviour change.

Studies such as the one conducted by Jovanović et al. (2013) underscore the role of education in building awareness about energy efficiency. Their survey examined how formal and informal education systems address public knowledge on energy savings. The study was motivated by Serbia's energy consumption levels, which are two to three times higher than its GDP relative to EU averages. Results revealed that while formal education does not sufficiently cover energy-saving practices, citizens gain much of their knowledge on this topic through media, highlighting a gap in formal educational coverage. Similarly, Hiramatsu et al. (2014) found that environmental education for children

can positively influence household behaviour. The authors state that “children treated with environmental education in school encourage their families to engage in pro-environmental behaviours including energy-saving behaviours”. There is a growing interest in the introduction of education in schools aimed at saving electricity consumption. Gill and Lang (2018), using a comprehensive panel analysis among school children in the USA in the school year 2015/2016, showed that there is a connection between the lessons learned at school and behaviour at home when it comes to a set of instructions regarding saving electricity consumption, and that “energy education” can be a valuable instrument for policy makers in terms of increasing energy efficiency. On the other hand, they also showed that it is very difficult to influence permanent behaviour change.

Education targeted at young students has shown promising results. Pietrapertosa et. al (2021) investigated the impact of educating young people on electricity consumption with the aim of increasing energy efficiency in public buildings. The education of young people was carried out in public schools in Italy during the 2018/2019 school year, and the target group included children between 3 and 14 years old. The results showed that “an average decrease of 4% in natural gas consumption was observed in the school in which energy saving measures complemented technical interventions and a limited increase in electricity consumption (between 0.5% and 4.3% per capita), which led to savings on the energy bill of about 1,122 Euro”. Similarly, Keller et al. (2022) examined the energy literacy of young participants, more precisely 6,000 respondents in primary and secondary schools in Austria. Energy literacy was investigated on a “cognitive, affective and behavioural level, and it compares the putative energy-saving effectiveness of the workshops to that of conventional energy audits”. Results indicated that after ETSIT (Austrian Education Energy Initiative), workshop students’ energy literacy was raised, as well as their claim that they will make changes in energy consumption behaviour in the future.

Findings indicate that educational methods should be adapted to regional development stages in order to effectively promote low-carbon lifestyles. The findings obtained by Wang et al. (2020) imply that policymakers should adopt educational methods and interventions to promote low-carbon knowledge and awareness that reflect the different stages of educational development in regions. This approach can encourage residents to adopt low-carbon lifestyles, thereby reducing energy consumption and mitigating CO₂ emissions. Similarly, according to the study conducted by Amin et al. (2024), renewable energy and education lower CO₂ emissions by 0.46% and 0.22%, respectively. Finan-

cial development, urbanisation, and natural resource depletion all have a 0.14%, 0.03%, and 0.08% impact on the environment, respectively. The heterogeneous causality analysis reveals the feedback effect, i.e. bidirectional causal links between education, carbon emissions and the use of renewable energy. According to research conducted in 27 OECD countries, empirical evidence suggests that countries should increase the investments in education and renewable energy sectors, and plan for research and development in renewable energy for the purpose of ensuring environmental sustainability (Zafar et al., 2020).

Some countries are trying to influence responsible behaviour of the population with regard to the consumption of electricity not only through education, but also through the approval of discounts as a reward for the rational use of energy. Ristić & Vučković (2023) describe a government initiative offering discounts to households for rational electricity use, which successfully motivated a reduction in consumption. Namely, in the period of a global energy crisis due to rising gas prices, before the winter period of 2022-2023, the Government of the Republic of Serbia adopted a Conclusion which recommended for the Public Company “Elektroprivreda Srbije” Belgrade to calculate a discount for customers from the “household” category for their rational consumption of electricity. Discounts range from 15% to 30%, depending on energy savings of 5% to 30%.

Some countries are trying to reduce electricity consumption through smart metering systems. Stanojević (2018) presented a system for analysing electricity consumption and generating bills for smart metres, providing the subscribers with a detailed insight into their usage. A study in Cyprus found that households using smart monitors that track electricity costs achieved average savings of 25%, while those receiving verbal information saved about 10% (Georgiou et al., 2013). However, Filipović et al. (2019) found that providing information on energy-saving methods had little impact on consumer behaviour when electricity prices are very low, as is the case in Serbia. Their controlled experiment with 330 households demonstrated that non-price factors alone were insufficient to significantly change consumption patterns in this context.

In Bosnia and Herzegovina, a study on the residential building stock highlighted substantial energy savings potential, emphasising the importance of data-driven policy-making and the implementation of energy-saving measures at the individual household level (Zagora et al., 2017). The quantitative analyses presented in this paper show that the most significant energy saving potential at the level of Bosnia and Herzegovina lies in the single-family housing residential typologies. In comparison to the energy saving potential of 7.93%

in collective housing, the implementation of EE measures in single-family housing may result with the absolute savings of 47.30%

Contrary to the research presented above, research conducted by Chen et al. (2023) with regard to the data on electricity consumption in developing countries in the period from 1990 to 2019 showed that education leads to an increase in electricity consumption and that “a 1% increase in education causes an increase in energy consumption of 0.496353%”.

According to the study by Wang et al. (2022), empirical results show that financial development significantly increased the use of renewable energy; however, education did not make a positive difference. Additionally, bidirectional and unidirectional causalities were observed for financial development and education, respectively, toward renewable energy. This suggests that policymakers should combine financial development policies with educational initiatives to improve the efficiency of renewable energy use. According to the research of Cihan & Değirmenci (2024), the long-term average schooling rate has a negative effect on energy consumption in households, but income level has a positive effect on a panel basis. On the other hand, it was also found that the error correction mechanism works and that the income level has a positive effect on energy consumption in households in the short term, but the average schooling rate does not have a significant effect on energy consumption in households in the short term.

Considering the various findings of the previously mentioned research, it was interesting to investigate the impact of education on the reduction of electricity consumption in the Federation of Bosnia and Herzegovina.

RESEARCH METHODOLOGY AND DATA SOURCES

The main goal of this research was to determine the extent to which education of household owners can influence the reduction of electricity consumption, and the potential savings in energy consumption, household income and reduction of CO₂ emissions into the air, which such education projects can achieve. The research was conducted by means of two visits and consultations of 10,044 household owners living in the area of the Tuzla Canton, in the following cities/municipalities: Kalesija, Tuzla, Lukavac, Živinice, Banovići and Gračanica. During the first visit to the households in 2020, a survey was conducted and insight into electricity consumption for the period between August 2019 and July 2020 was carried out, and advice and recommendations related to savings were given with the aim of motivating households to take measures

to reduce energy consumption and change their habits. During the first visit, each household received a symbolic package for “energy saving” in which, in addition to thematic promotional material, there were also 4 LED light bulbs. Energy advisors immediately installed the light bulbs in the households.

In order to determine the effect of advising household owners on energy saving measures, after one year, data on individual household electricity consumption was collected again for the period between August 2020 and July 2021. The total duration of the project in terms of collecting data on electricity costs before and after consultations on energy savings lasted from August 2020 to August 2021.

Education regarding energy savings in households covered various aspects of the savings budget, from replacing ordinary light bulbs with energy-saving and LED bulbs to thermal insulation of residential spaces. Furthermore, the energy efficiency labels on household appliances were clarified, and the attention of household owners was drawn to how much can be saved by buying more energy efficient household appliances.

The research sample consisted of 10,044 respondents from the area of the Tuzla Canton (hereafter TK). Out of a total of 10,044 respondents, 25% or 2,509 are from the area of the city of Tuzla. This is followed by: Kalesija 1,505 (15%), Živinice 1,505 (15%), Banovići 1,514 (15%), Lukavac 1,508 (15%) and Gračanica 1,502 (15%). The convenience sample in question was created according to the availability of household owners at the time of the energy advisors' visit. Most respondents live in family houses (one unit), which is 73% of the respondents. This is followed by residential buildings with 15.3% of the respondents, and family houses with several separate units with 11.1%, while 0.3% of the respondents live in other buildings (barracks, prefabricated buildings and fig.). When it comes to the age of the buildings in which the respondents live, the data is as follows: 14.3% of them live in buildings that are over 50 years old, 41.3% live in buildings between 29 and 50 years old, 22.9% of them live in buildings between 21 and 28 years old, 15.6% of them live in buildings between 11 and 20 years old, while only 5.4% of the residents live in buildings up to 10 years old. When it comes to the surface area of the living space, the percentage is as follows: 25% of the respondents live in a building with an area between 101 and 150 m² of living space, 24.12% of them live in a building 76-100 m² in size, slightly more than 23% of the respondents live in a building 51-75 m² in size, while 10.54% live in a building with an area of 25-50 m², and 4.36% of them live in buildings with over 201 m² of living space. All of the above data will help to better understand the sample on which the research was conducted.

The main limitation of the conducted research is the insufficiently large research sample. In order for the research sample to be relevant, the number of respondents needs to encompass 5% of the total population of the Tuzla Canton. Observing the number of inhabitants by municipalities/local communities according to the last population census in Bosnia and Herzegovina dating from 2013, we can say that our research sample includes less than 5% and amounts to 3.195%. Another limitation of the conducted research is the emergence of the COVID-19 pandemic and the changes in behaviour patterns in the period when data on electricity consumption was collected after the education.

The results were processed through descriptive texts. Data on electricity costs per month before and after the education and replacement of 4 ordinary light bulbs with 4 LED bulbs will be shown in EUR. We ensured the accuracy of the data on electricity consumption by looking into the electronic database of “Elektroprivreda” Bosnia and Herzegovina, along with knowing the user code of each household. Namely, “Elektroprivreda” BiH offers its users an electronic insight into the state of the account, as well as an overview of all the transactions on the client’s analytical account. On the basis of value savings and knowledge of the emission factor for Bosnia and Herzegovina, we calculated the reduction of CO₂ emissions.

RESEARCH RESULTS AND DISCUSSION

Table 1 presents the results of the collected data regarding the average monthly price of electricity in households, by individual municipalities and cities of the Tuzla Canton. The data in the table are presented in EUR and represent weighted average electricity costs for the period from August 2019 to July 2020. These are the actual data on electricity consumption for the 10,044 households before the education on potential energy savings.

Table 1: Average electricity costs calculated for the period August 2019 - July 2020, before education

Municipality /City	August	Sept.	Octob.	Nov.	Dec.	January	Febr.	March	April	May	June	July	SUM (AVG)
Banovići	30.50	31.16	31.84	32.69	33.43	33.91	32.81	33.21	32.53	31.86	31.42	31.44	386.81
Gračanica	33.38	33.60	34.29	34.94	36.28	35.91	34.86	34.71	34.63	33.80	33.09	33.88	413.36
Kalesija	31.80	32.06	31.23	32.45	34.15	35.54	32.58	31.96	32.52	31.73	30.92	32.18	389.12
Lukavac	28.85	28.54	28.69	29.15	30.76	30.95	29.27	29.63	30.22	29.30	28.62	29.31	353.28
Tuzla	26.40	26.36	26.77	27.09	29.12	28.68	27.33	27.79	28.70	27.76	27.18	27.07	330.27
Živinice	29.84	29.93	30.10	30.94	33.17	33.26	32.19	31.39	31.62	30.76	30.04	30.52	373.77
Total	29.76	29.89	30.12	30.80	32.45	32.61	31.09	31.09	31.41	30.56	29.91	30.37	370.05

Source: Authors' calculation

After the energy advisors educated the household owners about the possibilities for energy savings and replaced four ordinary light bulbs with LED bulbs, data on electricity consumption were collected again. The weighted average costs of electricity, expressed in EUR, after the training are presented in Table 2.

Table 2: Average electricity costs calculated for the period August 2020 - July 2021, after education

Municipality /City	August	Sept.	Octob.	Nov.	Dec.	January	Febr.	March	April	May	June	July	SUM (AVG)
Banovići	28.99	29.63	30.32	31.20	32.13	32.21	31.33	31.74	31.00	30.36	29.95	29.95	368.83
Gračanica	32.52	32.72	33.17	33.99	35.30	34.97	34.34	33.85	33.34	32.70	32.31	32.27	401.49
Kalesija	29.76	29.68	29.58	29.89	30.41	30.66	29.93	29.51	29.68	28.92	28.46	28.56	355.02
Lukavac	27.40	27.58	27.58	28.23	29.45	29.48	28.64	28.37	28.58	27.93	27.25	27.03	337.52
Tuzla	25.96	25.97	26.41	26.91	27.97	27.87	26.77	26.70	26.60	25.95	25.30	25.29	317.71
Živinice	28.37	28.58	28.98	30.16	33.00	32.65	31.85	31.67	31.54	29.53	28.72	28.84	363.90
Total	28.55	28.73	29.06	29.76	31.04	30.97	30.11	29.96	29.78	28.91	28.34	28.33	353.51

Source: Authors' calculation

On the basis of the data presented in Table 1 and Table 2, the calculation of savings in electricity consumption by municipalities and cities of TK was made, and the data on the percentage value of the savings are shown in Table 3.

Table 3: Calculation of savings in electricity consumption expressed in percentages

Municipality /City	August	Sept.	Octob.	Nov.	Dec.	January	Febr.	March	April	May	June	July	SUM (AVG)
Gračanica	2.59%	2.62%	3.24%	2.71%	2.70%	2.61%	1.49%	2.46%	3.74%	3.26%	2.35%	4.74%	2.87%
Kalesija	6.42%	7.45%	5.27%	7.91%	10.98%	13.72%	8.15%	7.66%	8.74%	8.84%	7.96%	11.25%	8.76%
Lukavac	5.04%	3.35%	3.85%	3.14%	4.27%	4.75%	2.16%	4.24%	5.42%	4.67%	4.77%	7.78%	4.46%
Tuzla	1.66%	1.48%	1.33%	0.68%	3.94%	2.84%	2.07%	3.92%	7.34%	6.54%	6.92%	6.55%	3.80%
Živinice	4.95%	4.50%	3.75%	2.51%	0.49%	1.84%	1.03%	-0.89%	0.26%	3.98%	4.40%	5.51%	2.64%
Total	4.07%	3.88%	3.52%	3.40%	4.34%	5.03%	3.15%	3.64%	5.19%	5.40%	5.27%	6.72%	4.47%

Source: Authors' calculation

Electricity savings at the level of all municipalities/cities amount to 4.47% on average. Among these, the largest recorded savings of electricity were recorded in the municipality of Kalesija, averaging to 8.76%, while the lowest savings were recorded in the town of Živinice at 2.87%. The fact is that, due to the COVID-19 pandemic and during the period of data collection (from August 2020 to July 2021), a large number of people working from home could also have had an impact on electricity consumption. All family members spent more time at home, so this certainly had an impact on higher consumption of electricity and lower realised savings.

An overview of the savings in electricity costs and consumed kilowatt hours, before and after education, in the average and total value, is presented in Table 4.

Table 4: An overview of savings in electricity costs and consumed kilowatt hours, before and after education, in the average and total value

Municipality /City	Before education		After education		Savings		Total savings	
	Average consumption	kWh	Average consumption	kWh	AVG	kWh	Total	kWh
	(EUR)		(EUR)		(EUR)		(EUR)	
Banovići	386.81	4,571.18	368.83	4,358.67	17.98	212.51	164,501.23	321,736.44
Gračanica	413.36	4,884.95	401.49	4,744.65	11.87	140.30	17,843.91	210,874.08
Kalesija	389.12	4,598.55	355.02	4,195.53	34.10	403.02	51,325.27	606,546.83
Lukavac	353.28	4,174.92	337.52	3,988.76	15.75	186.16	23,755.38	280,734.02
Tuzla	330.27	3,903.02	317.71	3,754.56	12.56	148.46	31,519.17	372,484.17
Živinice	373.77	4,417.10	363.90	4,300.48	9.87	116.62	14,851.24	175,507.55
Total	370.05	4,373.11	353.51	4,177.70	16.54	195.41	166,079.34	1,962,676.5

Source: Authors' calculation

The total savings in electricity consumption in the 10,044 households that were included in the sample amount to EUR 166,079.34, or 1,962,676.5 kWh. In line with Pietrapertosa et al. (2021) and contrary to Chen et al. (2023) and Wang et al. (2022), this research showed a positive impact of education on the reduction of electricity consumption, as well as the reduction of CO₂ emissions. The reduction of CO₂ emissions was calculated according to the following formula:

$$\begin{aligned} & \text{Emission reduction of CO}_2 = \\ & = \text{Energy saving (kWh)} \times \text{Emission factor (kg CO}_2\text{/kWh)} \end{aligned}$$

The emission factor in the production of electricity is the amount of emissions of carbon dioxide (CO₂) or other pollutants emitted into the atmosphere per unit of electricity produced. This factor is usually expressed in kilograms of CO₂ per kilowatt-hour (kg CO₂/kWh) or megawatt-hour (kg CO₂/MWh). The emission factor for BiH is 1,195 tCO₂/MWh, which means that the emission factor for energy production in BiH is 1,195 kg CO₂/kWh.

Emission reduction of CO₂ = 1,962,676.5 kWh × 1.195 kg CO₂/kWh = 2,345,398.42 kg CO₂

The total savings in CO₂ emissions resulting from the reduction in electricity consumption amount to 2,345 tons of CO₂.

The reduction of CO₂ emissions by 2,345,398.42 kg resulted in a decrease of approximately 1117.81 global hectares (gha) in ecological footprint. This means that the amount of biologically productive land required to absorb CO₂ emissions has been reduced by 1117.81 hectares. Considering the average ecological footprint per person globally (which is around 2.7 gha annually), this reduction neutralizes the ecological footprint of more than 400 people on a global scale within one year.

CONCLUSION

The aim of the research was to determine whether education of household owners about possible energy savings can encourage greater savings in households. The sample consisted of 10,044 households from the area of the Tuzla Canton in the Federation of Bosnia and Herzegovina. The results of the research showed that after the education and the replacement of 4 ordinary bulbs with 4 LED bulbs, households actually saved more electricity. Electricity savings on average, at the level of all municipalities/cities, amounted to 4.47%.

The total savings in electricity consumption amount to EUR 166,079.34, i.e. 1,962,676.5 kWh. The total savings in CO₂ emissions and contribution to reducing pollution amounted to 2,345 tCO₂. A reduction of CO₂ emissions by 2,345,398.42 kg resulted in a decrease of approximately 1117.81 global hectares (gha) in ecological footprint. The results of the research suggest that educating household owners about potential electricity savings results in savings in electricity consumption. This is particularly significant in the context of the 23% increase in electricity prices for households from August 2024. The subject price increase is just the beginning, because by the end of 2024, an additional increase in prices is expected for both households and business entities. In light of such an increase in prices, household owners will have an even greater incentive to achieve savings in energy consumption. The results of the research point to the fact that the total savings in electricity consumption and reduced pollution greatly exceed the costs of education for household owners. The results of the research are particularly significant when placed in the context of the country and the emissions trading system. Bosnia and Herzegovina have a high emission factor because electricity production is mainly obtained by burning fossil fuels. The results of the study in Tuzla Canton are consistent with the broader findings observed in the literature regarding the impact of education on energy consumption reduction. Education initiatives aimed at raising awareness and encouraging behavioural change have been shown to lead to reduced energy usage in various contexts.

When it comes to the limitations of the conducted research, it is, first of all, a relatively small sample because 10,044 households make up only 3,195% of the population of the Tuzla Canton. Another limitation in the research is the emergence of COVID-19, which caused a greater change in behaviour patterns and prompted people to spend more time in their homes, which could have affected the higher consumption of electrical energy and the lower displayed value of energy savings due to education and replacing four ordinary light bulbs with four LED bulbs in the households. A recommendation for future research on the impact of education on energy savings and the value of savings in electricity consumption is to increase the research sample in times of more stable external conditions which will not have a major impact on the change in people's behaviour.

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lecting electricity consumption data from 10,044 households in the Tuzla Canton. The authors of this paper were involved in processing the collected data and have obtained permission for its publication.

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THE INFLUENCE OF ENERGY EFFICIENCY MEASURES AND THE INSTALLATION OF HEAT DISTRIBUTORS ON THE HEAT CONSUMPTION IN BUILDINGS: CASE STUDY IN THE CITY OF ZAGREB / UTJECAJ MJERA ENERGETSKE UČINKOVITOSTI I UGRADNJE RAZDJELNIKA TOPLINE NA POTROŠNJU TOPLINSKE ENERGIJE U ZGRADARSTVU U GRADU ZAGREBU

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Buildings in the European Union accounts for over 40% of total energy consumption, of which 44% is energy for space heating. Given that the vast majority of buildings do not have adequate thermal protection, a large percentage of heat energy is lost and it is necessary to solve this problem. Central heating systems offers great potential for efficient, cost-effective and low-carbon heating, but the decarbonisation potential of said systems is untapped because heating sector is still dominated by fossil fuels. Energy efficiency in buildings refers to maintaining thermal comfort, lighting levels and indoor climate condition, implies encouraging the use of energy-efficient technologies, materials and services. Also, it refers to raising citizens' awareness of efficient energy consumption. Heat distributors, devices for local distribution of heat energy, are categorized as one of the measures of energy efficiency which enables a fairer distribution of heat energy. The problem of the European Union is the large number of old buildings, so in 2021, the share of buildings built before

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2000 amounted to 85%, of which 75% had poor energy efficiency. In the same year, 27% of the final energy consumption in the European Union was related to residential sector, while space heating and domestic hot water accounted for 78.9% of that final consumed energy in residential buildings. Only 1% of buildings annually improve their energy efficiency through energy renewal. An analysis of delivered energy for space heating through central heating system to residential buildings in the area of the city of Zagreb in the period from 2014 to 2022 concluded that the amount of delivered heat energy decreased by 3.82% while simultaneously increasing the number of new customers compensated the impact of energy efficiency measures and the results of the revitalisation of the hot water pipes. In order to better understand the effects of the energy renewal and the impact of the installation of heat distributors, a case study was made on the consumption of heat energy in buildings in Zagreb. Case study included three residential buildings that implemented different efficiency measures in the period from 2015 to 2023. The results showed that the building that installed heat distributors and carried out an energy renewal undoubtedly achieved the greatest savings and reduced the consumption of heat energy by 36% in the observed period. The lowest energy saving was achieved by the building that carried out only energy renewal and reduced the consumption of heat energy by 10% in the same period.

Keywords: buildings, heating, heat distributors, energy renewal, energy efficiency

JEL classification: O13, Q4

Zgradarstvo u Europskoj uniji čini preko 40 % ukupne potrošnje energije, od čega čak 44 % čini toplinska energija, odnosno zagrijavanje prostora. S obzirom na to da velika većina stambenih zgrada nema odgovarajuću toplinsku zaštitu, veliki se postotak toplinske energije gubi te je nužno riješiti taj problem. Centralizirana priprema toplinske energije jedan je od najjeftinijih i najučinkovitijih oblika grijanja prostora. Nudi velik potencijal za učinkovito, isplativo i niskougljično grijanje, no potencijal dekarbonizacije centralnog grijanja neiskorišten je jer sektorom grijanja još uvijek dominiraju fosilna goriva s udjelom od oko 63 % globalne potrošnje energije za grijanje zgrada. Energetska učinkovitost u zgradarstvu odnosi se na zadržavanje toplinske ugodnosti, razine rasvjete, unutarnjih klimatskih uvjeta i slično, a podrazumijeva poticanje primjene energetske isplativih i energetske učinkovitih tehnologija, materijala i usluga te

podizanje svijesti građana o učinkovitoj potrošnji energije. Razdjelnici topline, uređaji za lokalnu razdiobu toplinske energije, kategoriziraju se kao jedna od mjera energetske učinkovitosti, a omogućuju pravedniju raspodjelu toplinske energije. Problem Europske unije jest velik broj starih zgrada te je tako 2021. godine udio zgrada izgrađenih prije 2000. godine iznosio 85 %, a čak 75 % tih zgrada imalo je lošu energetska učinkovitost. Također, iste godine 27 % konačne potrošnje energije u Europskoj uniji odnosilo se na stambeni sektor, a grijanje prostora i potrošne tople vode činilo je zajedno čak 78,9 % finalne energije potrošene u stambenom sektoru. Samo 1 % zgrada godišnje poboljšava svoju energetska učinkovitost renoviranjem. Analizom isporučene toplinske energije na području grada Zagreba u razdoblju od 2014. do 2022. godine utvrđeno je da se količina isporučene ogrjevnice topline smanjila za 3,82 % uz istovremeno povećanje broja krajnjih kupaca za 7,35 % te je evidentno da priključenje novih krajnjih kupaca kompenzira utjecaj mjera energetske učinkovitosti i rezultate provedene revitalizacije vrelavoda. Radi što boljeg razumijevanja učinaka same energetske obnove i utjecaja ugradnje razdjelnika, provedena je studija slučaja u kojoj je analizirana potrošnja toplinske energije u trima zgradama koje su provele različite mjere energetske učinkovitosti na području grada Zagreba u razdoblju od 2015. do 2023. godine. Rezultati studije slučaja pokazali su da je zgrada koja je ugradila razdjelnike topline i provela energetska obnovu ostvarila nedvojbeno najveću uštedu toplinske energije te je u promatranom razdoblju smanjila potrošnju toplinske energije za 35,98 %. Najmanju uštedu toplinske energije ostvarila je zgrada koja je provela isključivo energetska obnovu te je u istom razdoblju uštedjela samo 10,23 % toplinske energije.

ključne riječi: zgrade, grijanje, razdjelnici topline, energetska obnova, energetska učinkovitost

JEL klasifikacija: O13, Q4

1. UVOD

Konstantna rastuća potražnja za energijom glavni je čimbenik gospodarskog razvoja. Neracionalna potrošnja neobnovljivih izvora energije dovela je do povećanja njihove cijene uz istovremeno smanjenje resursa. Upravo zbog toga, danas se sve više pažnje posvećuje pronalasku alternativnih obnovljivih izvora energije kao i uštedi energije.

Zgradarstvo u Europskoj uniji (nadalje EU) čini preko 40 % ukupne potrošnje energije, od čega većinu čini toplinska energija. Budući da velika većina zgrada starije gradnje nema odgovarajuću toplinsku zaštitu, poprilična se količina toplinske energije gubi. Višestambene zgrade imaju potencijal ostvarenja značajnih energetske ušteda provedbom mjera energetske učinkovitosti te iz tog razloga energetska učinkovitost zgrada postaje prioritet, kako u EU-u, tako i u Hrvatskoj.

Energetska učinkovitost u zgradarstvu podrazumijeva poticanje primjene energetske isplativih i učinkovitih tehnologija, materijala i usluga te podizanje svijesti građana o učinkovitoj potrošnji energije. Zgrade mogu provesti energetske obnovu kako bi povećale svoju energetske učinkovitost. Uz provođenje energetske obnove, ugradnja razdjelnika topline doprinijet će još većoj uštedi toplinske energije. Razdjelnici topline omogućuju pravedniju raspodjelu toplinske energije te su izvrstan alat uštede energije ako su ispravno postavljeni u zgradi koja je energetske učinkovita i u kojoj su stanari zgrade motivirani na racionalno korištenje energije.

2. TOPLINSKA ENERGIJA I SUSTAV TOPLINARSTVA

Toplinska energija čini gotovo polovicu globalne finalne potrošnje energije od čega se 44 % troši u zgradama za grijanje prostora, zagrijavanje potrošne tople vode i manjim dijelom za kuhanje. Sektorom grijanja još uvijek dominiraju fosilna goriva, dok obnovljivi izvori energije zadovoljavaju manje od jedne četvrtine potražnje za toplinskom energijom 2021. (IEA, 2022).

Sustav toplinarstva predstavlja energetske model grijanja gdje se toplinska energija centralno proizvodi te potom distribuirati do krajnjih potrošača (International District Energy Association). Jedan je od najjeftinijih i najučinkovitijih oblika grijanja prostora te nudi velik potencijal za učinkovito, isplativo i niskougljično grijanje, no potencijal dekarbonizacije centralnog grijanja još uvijek je neiskorišten. Centralno grijanje trenutačno predstavlja gotovo 4 % globalne emisije CO₂. Europa je treći najveći emiter, ali u prosjeku ima niži intenzitet ugljika u usporedbi s ostatkom svijeta te trenutačno predvodi integraciju obnovljivih izvora energije u sustavima centralnog grijanja s oko 25 % toplinske energije proizvedene iz njih. Industrija centralnog grijanja polako prelazi na mreže niže temperature, a inovativni razvoj uključuje solarne sustave centralnog grijanja, toplinske pumpe velikih razmjera, integraciju geotermalne i otpadne topline, koji najbolje funkcioniraju pri niskim radnim temperaturama (IEA, 2023).

2.1. PROIZVODNJA TOPLINSKE ENERGIJE

Toplinska energija u načelu se najčešće proizvodi na mjestu gdje se i koristi, ali u većim gradovima i industrijskim centrima toplinska se energija koristi i kao energija koja uz električnu energiju pokreće mnoštvo tehnološko-proizvodnih procesa. U takvim sredinama toplinska energija proizvodi se centralizirano u termoelektranama/toplanama iz kojih se sustavima prijenosa topline dovodi do korisnika, a riječ je o centraliziranim toplinskim sustavima. Prilikom proizvodnje toplinske energije koristi se transformacija energije korištenog energenta, a potom se transformirana energija u obliku pare ili vrele vode prenosi za potrebe kupaca. Budući da je usko povezana sa zaštitom okoliša, podložna je unapređivanjima i težnji za što učinkovitijom pretvorbom energije (HEP Proizvodnja d.o.o.).

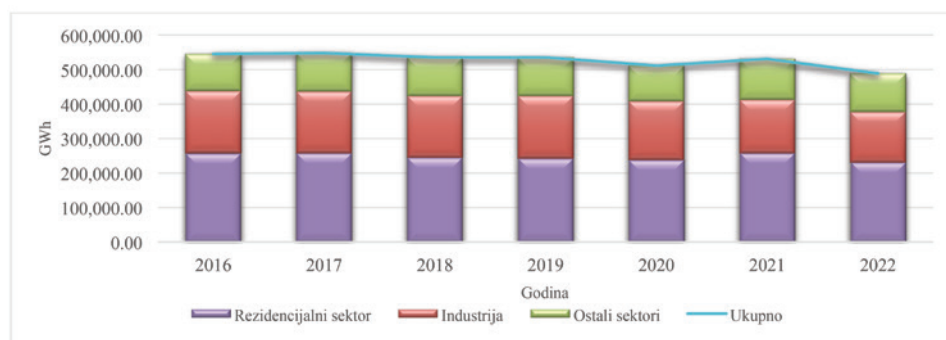
Važno je istaknuti pojam kogeneracije koji označava istovremenu proizvodnju dvaju transformiranih oblika energije, odnosno toplinske i električne energije. Temelji se na povećanju učinkovitosti istovremene proizvodnje, a glavni zadatak kogeneracijskog postrojenja jest zadovoljiti potrebe za toplinskom energijom, dok se električna energija u tom smislu smatra nusproizvodom (Sutlović, 2020). Primjenom kogeneracijskih postrojenja povećava se učinkovitost spojne proizvodnje u odnosu na odvojenu proizvodnju toplinske i električne energije te se postiže i proporcionalno smanjenje onečišćenja okoliša. Danas su kogeneracijska postrojenja, uz obnovljive izvore energije, veoma poticani energetske sustavi (Staniša, Prelec, Jakovljević, 2010).

2.2. TOPLINARSTVO U EUROPSKOJ UNIJI I HRVATSKOJ

Danas su sustavi centralnog grijanja u Europi uglavnom u vlasništvu i pod upravom javnih subjekata, a nacionalna tržišta centralnog grijanja visoko su koncentrirana te nekoliko dobavljača kontrolira više od 70 % tržišta. Budući da su prirodni monopoli, podliježu nekoj vrsti regulacije u većini zemalja. Za razliku od drugih energetske tržišta, većina država članica EU-a sustav toplinarstva smatra integriranom uslugom u kojoj proizvodnjom, radom mreže i distribucijom na integrirani način upravlja jedno poduzeće. Tržišne situacije razlikuju se među zemljama EU-a, a posebno u pogledu razvoja sustava centralnog grijanja te kombinacije korištene energije (Europska komisija, 2022). Sustav toplinarstva u potpunosti je razvijen tek u zemljama koje su energetske planiranje smatrale prirodnim dijelom urbanističkog planiranja infrastrukture (RAMBOLL, 2020).

Sustavi centralnog grijanja u europskim zemljama u vrlo su različitim fazama razvoja. Zemlje članice EU-a koje imaju takav sustav možemo kategorizirati na temelju njihova udjela centralnog grijanja u njihovoj ukupnoj potražnji za toplinom, a razvijene su kategorije s malim ($< 10\%$), srednjim ($10\% - 50\%$) i velikim ($> 50\%$) udjelom. Zemlje s malim udjelom su Slovenija, Hrvatska, Nizozemska, Francuska, Italija, Grčka, Španjolska, Portugal, Irska i Belgija. Zemlje u ovoj kategoriji imaju općenito visok udio individualnog grijanja s visokim udjelom fosilnih goriva, uglavnom prirodnog plina. Postoji nedostatak svijesti i praktičnog znanja o tome kako implementirati sustave centralnog grijanja, što se očituje u nedostatku zakonskih i regulatornih okvira te planovima koji trenutačno pogoduju pojedinačnim rješenjima. Visoki troškovi ulaganja zahtijevaju stabilan okvir koji omogućuje dugoročna ulaganja. Zemlje sa srednjim udjelom su Poljska, Češka, Finska, Latvija, Rumunjska, Mađarska, Bugarska, Austrija i Njemačka. Za proizvodnju toplinske energije koriste se primarno fosilna goriva. Stanje postojećih mreža varira jer neke mreže nisu održavane na odgovarajući način tijekom godina te ostvaruju velike gubitke toplinske energije i opadajuću potražnju za toplinom jer potrošači prelaze na individualna rješenja. Obnova postojećih mreža ključna je za održavanje tržišnog udjela. Zemlje s velikim udjelom su Danska, Litva, Slovačka, Estonija i Švedska. Ovim zemljama širenje tržišta nije primarno fokusno područje već povećanje ukupne učinkovitosti mreža korištenjem obnovljivih izvora energije i novih tehnologija. Nekoliko zemalja započelo je prijelaz s fosilnih goriva, a u tom prijelaznom periodu kruta biomasa jest najlakše rješenje jer može poslužiti kao izravna zamjena za ugljen u termoelektranama i kogeneracijskim postrojenjima (RAMBOLL, 2020).

Grafički prikaz 1. Konačna potrošnja toplinske energije u EU-u u razdoblju od 2016. do 2021. godine iskazana u GWh

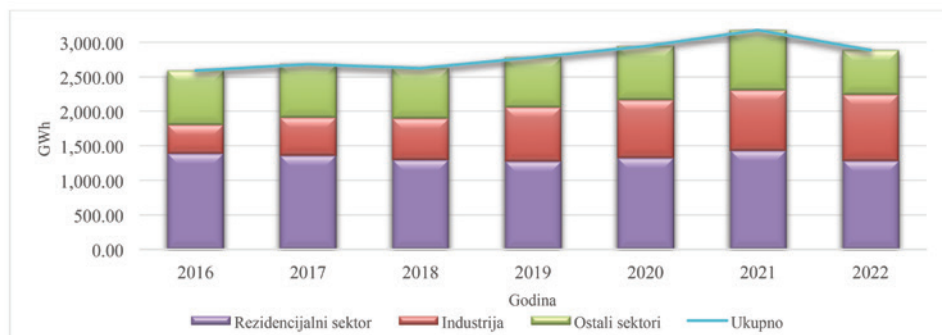


Izvor: izrada autora prema podacima Eurostata (preuzeto iz Marelja, 2024)

EU tijekom promatranog razdoblja ima silazni trend konačne potrošnje toplinske energije te je ona, uz prosječnu godišnju stopu pada od 1,5 %, 2022. bila za 10,43 % manja u odnosu na 2016. godinu. Konačna potrošnja toplinske energije u rezidencijalnom sektoru smanjila se u promatranom razdoblju za 10,42 % s prosječnom godišnjom stopom pada od 1,42 %. Na smanjenje konačne potrošnje toplinske energije u rezidencijalnom sektoru svakako su utjecale više temperature zraka te provođenje mjera energetske učinkovitosti, što je u konačnici dovelo do manje potrebe za toplinskom energijom. Konačna potrošnja toplinske energije u industriji u promatranom razdoblju smanjila se za 18,24 % uz prosječnu godišnju stopu pada od 2,77 %. Isto je uzrokovano politikama EU-a koje se odnose na klimatske promjene, pogotovo u energetske intenzivnim industrijama. Konačna potrošnja toplinske energije u ostalim sektorima, što obuhvaća komercijalne i javne usluge, agrikulturu, šumarstvo i ribarstvo, ostvarila je rast od ukupno 2,66 % s prosječnom godišnjom stopom rasta od 0,6 %. Postotni udio konačne potrošnje toplinske energije u rezidencijalnom sektoru u ukupnoj konačnoj potrošnji jest najveći te nijedne godine u promatranom razdoblju nije pao ispod 45 %. Hrvatska pripada maloj kategoriji udjela centralnog grijanja sa samo 6,3 %. Bez obzira na to, sektor toplinarstva jedan je od četiriju važnih energetske sektora u Republici Hrvatskoj uz plinski, naftni i elektroenergetski sektor (Ercegović, 2020 prema Krklec, 2019).

U 2022. godini energetske djelatnostima proizvodnje, distribucije i opskrbe toplinskom energijom bavilo se 11 poduzeća u 16 gradova u Hrvatskoj, koja pružaju uslugu grijanja prostora i pripremu potrošne tople vode za više od 160 359 kupaca toplinske energije u većim kontinentalnim gradovima, pri čemu više od 95 % ukupnog broja kupaca pripada kategoriji kućanstva. Toplinska energija proizvodi se u kogeneracijskim postrojenjima u Zagrebu, Osijeku i Sisku ili u mini toplanama, odnosno blokovskim i kućnim kotlovnica za pojedina naselja, zatim se vrelvodima, toplovodima i parovodima ukupne duljine oko 447 km distribuira do objekata. Također, u Zagrebu, Osijeku i Sisku proizvodi se i isporučuje tehnološka para za industrijske potrebe i djelomično za potrebe grijanja prostora (Ministarstvo gospodarstva i održivog razvoja, 2023).

Grafički prikaz 2. Konačna potrošnja toplinske energije u Hrvatskoj u razdoblju od 2016. do 2022. godine iskazana u GWh



Izvor: izrada autora prema podacima Eurostata (preuzeto iz Marelja, 2024)

Hrvatska tijekom promatranog razdoblja ima porast konačne potrošnje toplinske energije za ukupno 11,57 % s prosječnom godišnjom stopom rasta od 1,73 %, a za to je najviše zaslužna industrija. Konačna potrošnja toplinske energije u industriji ostvarila je rast u promatranom razdoblju za čak 127,60 % s prosječnom godišnjom stopom rasta od 13,05 %. Iako u Hrvatskoj industrija gotovo svakodnevno raste, problem je upotreba zastarjele tehnologije i nedovoljna ulaganja u industriju. Suprotno industriji, konačna potrošnja toplinske energije u rezidencijalnom sektoru u promatranom razdoblju smanjila se za ukupno 7,42 % s prosječnom godišnjom stopom pada od 0,95 %. S obzirom na to da je broj novih stambenih građevina i broj korisnika toplinske energije u Hrvatskoj u stalnom porastu, vidljiv je efekt mjera energetske učinkovitosti i sve većeg broja energetskih obnova starih građevina. Konačna potrošnja toplinske energije u ostalim sektorima, što obuhvaća komercijalne i javne usluge, agrikulturu, šumarstvo i ribarstvo, također je ostvarila pad potrošnje od ukupno 17,34 % s prosječnom godišnjom stopom pada od 2 % u promatranom razdoblju. Rezidencijalni sektor evidentno je najveći potrošač toplinske energije u Hrvatskoj, što nam pokazuje postotni udio u ukupnoj konačnoj potrošnji toplinske energije koji nijedne godine u promatranom razdoblju nije iznosio manje od 44 %.

3. ENERGETSKA UČINKOVITOST U ZGRADARSTVU I UGRADNJA RAZDJELNIKA TOPLINE

Zgrade su složeni energetske sustavi te su ujedno i najveći konzumenti energije (Šandrk Nukić, 2020 prema Balaras *et al.*, 2005). Zgradarstvo je na području Europe zaslužno za čak 40 % ukupne primarne potrošnje energije (Šandrk Nukić, 2020 prema Europski parlament i Vijeće, 2010), dok je u Hrvatskoj zgradarstvo, koje uključuje stambene i nestambene zgrade, zaslužno za čak 42 % ukupne potrošnje energije (Šandrk Nukić, 2020 prema FZOEU, 2019). Potrošnja energije uvelike ovisi o karakteristikama zgrade, odnosno obliku i konstrukcijskim materijalima, energetske sustavima te o klimatskim uvjetima područja gdje se zgrade nalaze (FZOEU). Pretpostavka je da se velika količina energije troši u zgradama građenim prije nekoliko desetljeća koje imaju nisku razinu energetske učinkovitosti te ne udovoljavaju suvremenim preporukama i propisima. Takve će se zgrade vjerojatno još dugo koristiti te je neophodna njihova energetska obnova koja ima potencijal u smislu smanjenja ukupne potrošnje energije i poboljšanja energetske učinkovitosti (Šandrk Nukić, 2020). Godine 2021. udio zgrada izgrađenih prije 2000. u EU-u iznosio je 85 %, a čak 75 % tih zgrada imalo je lošu energetske učinkovitost. Samo 1 % zgrada godišnje poboljšava svoju energetske učinkovitost renoviranjem (Europska komisija).

Sektor zgradarstva ključno pridonosi emisijama stakleničkih plinova te predstavlja jednu trećinu emisija povezanih s energijom u EU-u. Povijesni podaci o emisijama stakleničkih plinova iz sektora zgradarstva u EU-u pokazuju trend pada od 2005., što je rezultat provedbe viših standarda za nove zgrade, mjera za povećanje energetske učinkovitosti, mjera za dekarbonizaciju elektroenergetskog sektora, ali i viših temperatura (EEA, 2021).

Energetske učinkovitost u zgradarstvu odnosi se na osiguravanje minimalne potrošnje energije prilikom postizanja optimalne ugodnosti boravka i korištenja zgrade. Podrazumijeva poticanje primjene energetske isplativih i energetske učinkovitih tehnologija, materijala i usluga te podizanje svijesti građana o učinkovitoj potrošnji energije (Tokić, 2014).

Uz provođenje energetske obnove zgrade, savjetuje se ugradnja razdjelnika topline kako bi se ostvario sinergijski učinak više mjera energetske učinkovitosti. Razdjelnici topline jesu uređaji za lokalnu razdiobu isporučene toplinske energije koji se ugrađuju na ogrjevna tijela u zgradama u kojima su svi prostori spojeni na jedno zajedničko mjerilo toplinske energije, a u kojima se troškovi toplinske energije obračunavaju sukladno površini ili snazi prostora umjesto stvarne individualne potrošnje. Njihovom ugradnjom omogućuje se pravednija

raspodjela toplinske energije. Razdjelnik topline registrira impulse sukladno razlici temperatura između ogrjevnog tijela i okolnog prostora te parametara programiranja. Impulsi koje registrira razdjelnik bezdimenzionalna su veličina te nemaju jediničnu cijenu. Vrijednost impulsa promjenjiva je iz mjeseca u mjesec jer ovisi o ukupnoj količini toplinske energije isporučene na zajedničko mjerilo toplinske energije obračunskog mjernog mjesta i ukupnoj količini impulsa očitanih s razdjelnika svih prostora na tom obračunskom mjernom mjestu. Kako bi sustav s ugrađenim razdjelnicima bio tehnički funkcionalan te kako bi se ostvarile energetske uštede i pravednija raspodjela toplinske energije, najmanje 80 % svih prostora na zajedničkom mjerilu toplinske energije mora ugraditi razdjelnike topline (HEP-TOPLINARSTVO d.o.o.). Uz razdjelnike topline bitno je i zakonski obvezno ugraditi termostatski ventil koji potrošaču omogućava namještanje željene topline unutar prostorije. Za razliku od starog sistema obračuna toplinske energije po površini, gdje su ogrjevna tijela grijala maksimalno bez mogućnosti smanjenja, termostatski ventil omogućava regulaciju koja će dovesti do uštede energije i manjih izdataka za grijanje (Gelo, Čenan i Ercegović, 2021).

Prema očitanjima obračunskih mjerila HEP-TOPLINARSTVA d.o.o., ukupna potrošnja toplinske energije cijele zgrade se u većini slučajeva nakon ugradnje razdjelnika smanjila od 15 % do 30 % u odnosu na razdoblje prije ugradnje. S obzirom na navedeno, važno je istaknuti da ugradnja razdjelnika topline ne mora nužno značiti uštedu energije i niže troškove za prostor u koji su razdjelnici ugrađeni. Potrebno je uzeti u obzir da na potrošnju toplinske energije pojedinog prostora utječe niz faktora kao što je podešavanje termostata na ogrjevnom tijelu, tehničke karakteristike zgrade, položaj prostora u zgradi i navike potrošača (HEP-TOPLINARSTVO d.o.o.).

Razdjelnici topline izvrstan su alat uštede energije ako su ispravno postavljeni u zgradi koja je energetski učinkovita, ali imaju i određene nedostatke. Anomalija obračuna toplinske energije prema očitanku razdjelnika (model 3EG) najčešće se pojavljuje u mjesecima kada je potreba ljudi za grijanjem manja kao što to često bude na početku i na kraju sezone grijanja. Primjer je stan veličine 54 m² u Zaprešiću kojem je račun za svibanj 2020., kada je sezona grijanja bila na samom zalasku, iznosio 102,81 € s utrošenih 156 impulsa. Budući da je cijelo obračunsko mjerilo utrošilo ukupno 340 impulsa, predmetni stan imao je najveći broj očitanih impulsa u odnosu na ostale krajnje kupce i sukladno tome najveću količinu energije, što je utjecalo na visinu računa za isporučenu toplinsku energiju. Navedeno potvrđuje da impuls nije mjerna jedinica i nema svoju fiksnu cijenu. Također, kolektivni strah od velikih iznosa računa, pogotovo kod socijalno ugroženih skupina ljudi, utječe na to da se pojedinci ne griju putem

sustava centralnog grijanja već koriste klime i grijalice na struju. Nekolicina krajnjih kupaca pojedine prostorije u stambenom prostoru uopće ne grije, već koriste samo jedno ogrjevno tijelo podešeno na maksimum, što dovodi do veće potrošnje nego što bi to bio slučaj kada bi koristili više ogrjevnih tijela podešenih na srednju jačinu. Naime, budući da se uz razdjelnike topline ugrađuje i termostat, kojem je svrha regulacije rada ogrjevnih tijela, korištenjem jednog ogrjevnog tijela postiže se kontraefekt zato što to jedno ogrjevno tijelo pokušava zagrijati sve prostorije u stanu i time se troši velika količina toplinske energije. Navedeno utječe na pojavu vlage u stambenim prostorima i neravnomjerno cirkuliranje toplinske energije u sustavu centralnog grijanja.

Ugradnja razdjelnika topline bila je aktualna do 2016. godine kada je zastavljena nakon analiza i velikoj broja kritika građana. Trenutačno oko 100 000 kućanstava ima ugrađene razdjelnike, dok ostala kućanstva nisu ugradila takve sustave zbog analiza koje su utvrdile nedostatke (Gelo, Čenan i Ercegović, 2021).

3.1. ENERGETSKA POLITIKA EUROPSKE UNIJE I HRVATSKE

Postojeći europski regulatorni okvir za energiju temelji se na energetske paketu pod nazivom *Paket za 55* koji predstavlja središnji dio Europskog zelenog plana kojim se energetske ciljevi usklađuju s novim europskim klimatskim ambicijama za smanjenje emisija za najmanje 55 % do 2030. godine u odnosu na razine iz 1990. i postizanje ugljične neutralnosti do 2050. godine te se između ostalog usredotočuje na obnovljive izvore energije i energetske učinkovitost (Ciucci, 2023). Nova Direktiva o energetske učinkovitosti (2023/1791/EU) za razdoblje do 2030. godine, revidirana u sklopu navedenog paketa, temelji se na načelu *energetske učinkovitost na prvom mjestu*. Direktivom se od država članica zahtijeva određivanje okvirnih nacionalnih ciljeva u području energetske učinkovitosti te se utvrđuju nove godišnje obveze u pogledu uštede energije za države članice koje će tako morati smanjiti potrošnju konačne energije za 1,3 % od 2024., 1,5 % od 2026. i 1,9 % od 2028. godine (Ciucci, 2024).

Direktivom o energetske svojstvima zgrade (2010/31/EU) traži se postupno uvođenje solarnih uređaja u javne i nestambene zgrade i u sve nove stambene zgrade ako je to ekonomski i tehnički prikladno. Sve nove zgrade morat će imati nultu stopu emisija od 2030. godine, države članice definirat će minimalne standarde energetske svojstava za obnovu 16 % fonda nestambenih zgrada s najlošijim svojstvima do 2030. te 26 % do 2033. godine te će osigurati plan za postupnu obnovu cijelog fonda stambenih zgrada (Ciucci, 2024).

3.2. PROGRAMI ENERGETSKE OBNOVE U HRVATSKOJ

Ministarstvo prostornoga uređenja, graditeljstva i državne imovine Republike Hrvatske u prosincu 2020. donijelo je Dugoročnu strategiju obnove nacionalnog fonda zgrada do 2050. godine koja obuhvaća pregled nacionalnog fonda zgrada, utvrđivanje troškovno učinkovitog pristupa energetskej obnovi, pregled politika i mjera, procjene očekivane uštede energije i širih koristi te pregled nacionalnih inicijativa za promicanje pametnih tehnologija i dobro povezanih zgrada i zajednica. Nacionalni fond postojećih zgrada u RH 2020. godine obuhvatio je ukupnu korisnu površinu od 237.315.397 m², od čega se 178.592.460 m² odnosilo na stambene zgrade, a 58.722.937 m² na nestambene zgrade. Procjenjuje se da će potrebna ulaganja u sveobuhvatnu i energetske obnovu zgrada iznositi 32,28 milijardi eura u razdoblju do 2050. godine. Primarna točka pokreta energetske obnove zgrada u RH jesu bespovratna sredstva za energetske obnovu. Investicije u energetske obnovu zgrada generiraju niz širih koristi te osim energetske uštede koje se kumuliraju tijekom životnog vijeka zgrada, povećava se raspoloživi dohodak koji se usmjerava u potrošnju i na rast gospodarstva, povećava se vrijednost nekretnina, smanjuje se rizik za zdravlje i stopa siromaštva, povećava se sigurnost opskrbe energijom i produžuje životni vijek zgrada (Ministarstvo prostornoga uređenja, graditeljstva i državne imovine RH, 2020).

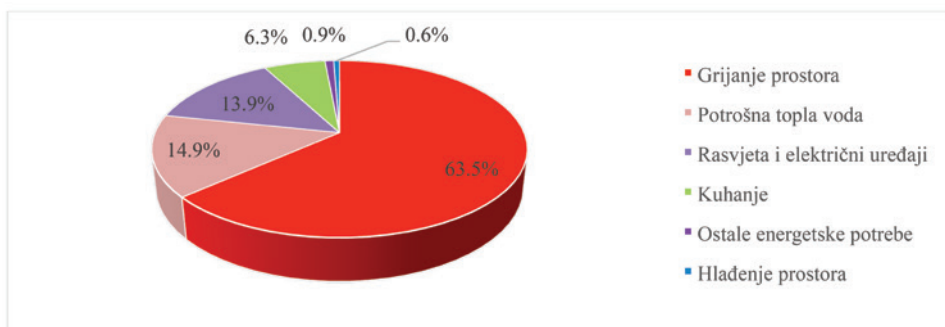
Krajem 2021. godine Vlada RH donijela je paket programa vezan za energetske obnovu zgrada u RH do 2030., a novac za njihovo provođenje osigurava se iz europskih fondova. Cilj programa jest postupno povećanje stope energetske obnove ukupnog fonda zgrada s 0,7 % godišnje na 3 %, odnosno 30 milijuna m² energetski obnovljenih zgrada do 2030. godine. Program energetske obnove višestambenih zgrada fokusira se na segment koji predstavlja oko 35 % ukupnog stambenog fonda, odnosno 27 % ukupnog fonda zgrada u Hrvatskoj. Na višestambene zgrade otpada oko 32 % ukupno isporučene energije sektoru kućanstva, a čak 80 % te energije troši se na toplinske potrebe. Naglasak Programa jest na zgradama s najlošijim energetskim svojstvima kojih je u kontinentalnoj Hrvatskoj oko 34 %, a u primorskoj Hrvatskoj oko 30 %.

4. ANALIZA POTROŠNJE TOPLINSKE ENERGIJE U ZGRADARSTVU

Zgradarstvo u EU-u odgovorno je za više od 40 % ukupne potrošnje energije te za čak 36 % emisija stakleničkih plinova, koji uglavnom proizlaze iz gradnje, uporabe, obnove i rušenja zgrada (Europska komisija, 2020). Budu-

ći da zgradarstvo obuhvaća stambene zgrade (obiteljske kuće i višestambene zgrade) i nestambene zgrade, u nastavku će fokus potrošnje energije u EU-u biti na potrošnji energije u stambenim zgradama.

Grafički prikaz 3. Potrošnja energije u kućanstvima EU-a



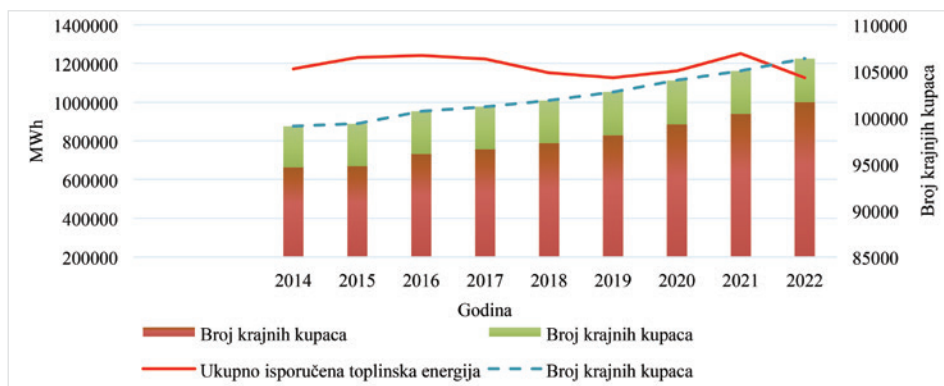
Izvor: izrada autora prema podacima Eurostata (2024)

U 2022. godini 25,8 % konačne potrošnje energije odnosilo se na stambeni sektor. Grijanje prostora i potrošne tople vode zajedno su činili čak 78,4 % finalne energije potrošene u stambenom sektoru (Eurostat, 2024). Godine 2019. se u Hrvatskoj na potrebe grijanja i hlađenja prostora te za pripremu potrošne tople vode odnosilo 80,69 % ukupno isporučene energije stambenom sektoru. Preostalih 19,31 % ukupno isporučene energije stambenom sektoru odnosilo se na ostale energetske potrebe (Ministarstvo prostornoga uređenja, graditeljstva i državne imovine, 2021). U Hrvatskoj je 2022. udio ukupne potrošnje finalne energije u zgradarstvu iznosio čak 47,3 %. Iste godine fond zgrada u Republici Hrvatskoj iznosio je 173.074.538 m² korisne površine grijanog dijela zgrada, od čega se 76,54 % odnosilo na stambene zgrade (Ministarstvo gospodarstva i održivog razvoja, 2023).

4.1. POTROŠNJA TOPLINSKE ENERGIJE U ZAGREBU

U Grafičkom prikazu 4. navedeni su podaci o ukupno isporučenoj toplinskoj energiji za grijanje prostora na području grada Zagreba te broj krajnjih kupaca u razdoblju od 2014. do 2022. godine. S obzirom na to da se tehnološka para isporučuje industriji za tehnološke potrebe, podaci o njoj nisu uključeni u analizu.

Grafički prikaz 4. Isporučena ogrjevnja toplina iskazana u MWh i broj krajnjih kupaca u Zagrebu u razdoblju od 2014. do 2022. godine



Izvor: izrada autora prema podacima HEP-TOPLINARSTVA d.o.o. (preuzeto iz Marelja, 2024)

U razdoblju od 2014. do 2022. godine količina isporučene ogrjevnje topline u Zagrebu smanjila se za ukupno 3,82 % s prosječnom godišnjom stopom pada od 0,30 %. U istom razdoblju broj krajnjih kupaca u Zagrebu povećao se za 7,35 % uz prosječnu godišnju stopu rasta od 0,79 %. Kategorija kućanstvo ostvarila je rast od 7,41 % s prosječnom godišnjom stopom rasta od 0,80 %, dok je kategorija poslovni prostori ostvarila rast od 6,18 % s prosječnom godišnjom stopom rasta od 0,68 %. Postotak udjela kategorije kućanstvo nije pao ispod 95 % nijedne od promatranih godina. Uzme li se u obzir da se u promatranom razdoblju količina isporučene ogrjevnje topline smanjila za 3,82 % uz istovremeno povećanje broja krajnjih kupaca od 7,35 %, evidentno je da je priključenje novih krajnjih kupaca kompenziralo utjecaj mjera energetske učinkovitosti i rezultate provedene revitalizacije vrelavoda.

4.2. STUDIJA SLUČAJA

Radi što boljeg razumijevanja učinaka energetske obnove zgrada i utjecaja ugradnje razdjelnika topline slijedi studija slučaja u kojoj će se analizirati potrošnja toplinske energije isključivo za grijanje prostora u trima zgradama starije gradnje, koje su provele različite mjere energetske učinkovitosti na području grada Zagreba u razdoblju od 2015. do 2023. godine. Podaci za analizu dobiveni su od strane HEP-TOPLINARSTVA d.o.o. za sve tri zgrade. Važno

je istaknuti da se provođenjem energetske obnove višestambenih zgrada, zbog promjene fizikalnih svojstava i smanjene potrebe za toplinskom energijom, smanjuje njihova ukupna priključna snaga, što utječe na smanjenje paušalnog dijela računa. HEP-TOPLINARSTVO d.o.o. takvim zgradama izdaje novu Termoenergetsku suglasnost.

Tablica 1. Specifikacija stambenih zgrada obuhvaćenih studijom slučaja

Zgrada	Ukupna grijana površina (m²)	Priključna snaga prije energetske obnove (kW)	Provedena energetska obnova	Priključna snaga nakon energetske obnove (kW)	Razdjelnici topline implementirani u obračun toplinske energije
A	4.377,75	648.303	/	/	siječanj 2016.
B	3.266,37	364.430	2020	232.888	/
C	3.165,36	383.790	2018	248.910	veljača 2016.

Izvor: izrada autora na temelju podataka HEP-TOPLINARSTVA d.o.o. (preuzeto iz Marelja, 2024)

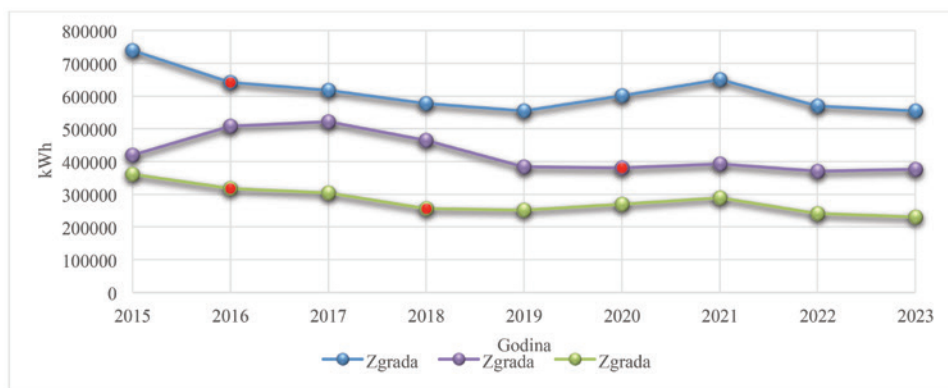
Zgrada A nalazi se u zagrebačkom naselju Utrine. Razdjelnici topline ugrađeni su krajem 2015. godine u 96,91 % grijane površine (4.242,49m²), a u obračun toplinske energije implementirani su od siječnja 2016. Omjer veličina UR : UPOV od početka iznosi 70 : 30. U međuvremenu, dio stanara vratio se na model obračuna po površini (2EG) te trenutačno 4.025,27 m² ukupne grijane površine obračunskog mjernog mjesta ima model obračuna 3EG (91,95 % ukupne grijane površine), dok preostalih 352,48 m² ima model obračuna 2EG uz korekcijski faktor 2 koji se nije mijenjao od obračunskog razdoblja za siječanj 2016. Energetska obnova nije provedena na predmetnoj zgradi (HEP-TOPLINARSTVO d.o.o., 2024.).

Zgrada B nalazi se u zagrebačkom naselju Srednjaci. 15. 11. 2017. potpisan je ugovor za bespovratna sredstva iz EU fonda za regionalni razvoj u svrhu energetske obnove predmetne zgrade. Prema opisu projekta, nakon energetske obnove koja je uključivala poboljšanje toplinske zaštite ovojnice, zamjenu vanjske stolarije te unutarnju rasvjetu zajedničkih prostora zgrade, projektirana ušteda energije za grijanje i hlađenje prostora iznosila je više od 65 % (Ministarstvo graditeljstva i prostornoga uređenja, 2018). Na temelju dostavljenog Elaborata instalirane snage grijanja za stambenu zgradu, izrađenog od strane projektantske tvrtke, HEP-TOPLINARSTVO d.o.o. je 15. 12. 2020. izdalo novu Termoenergetsku suglasnost za navedenu zgradu te smanjilo priključnu snagu. U ovoj zgradi obračun isporučene toplinske

energije vrši se prema modelu 2Eg, odnosno prema površini (HEP-TOPLINARSTVO d.o.o., 2024.).

Zgrada C nalazi se u zagrebačkom naselju Trnsko. Odlukom o načinu raspodjele toplinske energije iz veljače 2016., od istog obračunskog razdoblja, 90,21 % grijane površine (2.855,38 m²) krenulo je s modelom obračuna 3EG, dok je preostalih 9,79 % grijane površine (309,98 m²) ostalo na modelu obračuna 2EG uz korekcijski faktor 2. Omjer veličina UR : UPOV na početku je iznosio 60 : 40. Tijekom godina navedeni se omjer mijenjao te u konačnici od obračunskog razdoblja za siječanj 2020. pa sve do danas iznosi 80 : 20. Predmetna višestambena zgrada je osim ugradnje razdjelnika topline provela i energetska obnovu. Na temelju dostavljenog izvedbenog projekta od studenog 2017. za navedenu zgradu, koji je izrađen od strane projektantske tvrtke, HEP-TOPLINARSTVO d.o.o. je 6. 4. 2018. izdalo novu Termoenergetsku suglasnost za predmetnu zgradu te smanjilo priključnu snagu s postojećih 383.790 kW na traženih 248.910 kW. (HEP-TOPLINARSTVO d.o.o., 2024.).

Grafički prikaz 5. Isporučena toplinska energija za grijanje prostora zgradama obuhvaćenim studijom slučaja



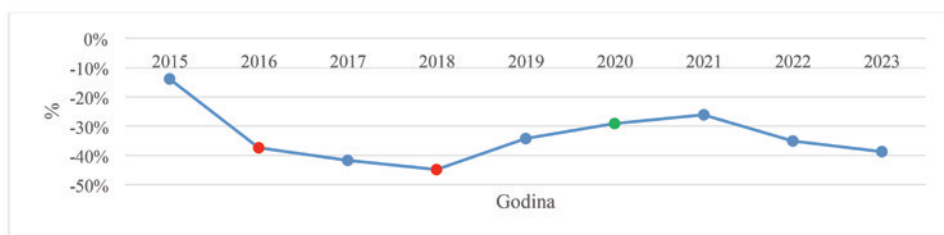
Izvor: izrada autora prema podacima HEP-TOPLINARSTVA d.o.o. (preuzeto iz Marelja, 2024)

Crvenom bojom na linijama potrošnje toplinske energije označene su godine kada su predmetne zgrade provele određenu mjeru energetske učinkovitosti. Za zgradu A označena je 2016. godina kada su se razdjelnici implementirali u obračun toplinske energije, a za zgradu B označena je 2020. godina koja prikazuje potrošnju toplinske energije nakon provedene energetske obnove. Za zgradu C označene su dvije godine, 2016. kada su razdjelnici topline implementirani u obračun toplinske energije te 2018. koja prikazuje ukupno isporučenu

energiju nakon provedene energetske obnove. Evidentna je ušteda energije u promatranom razdoblju za sve tri analizirane zgrade uz određene oscilacije koje su vezane uz različite temperaturne uvjete tijekom godina te ljudski faktor koji se tiče razdjelnika topline.

Budući da zgrada B i zgrada C imaju relativno slične karakteristike, obje su provele energetska obnove u različitim vremenskim razdobljima, a samo zgrada C ugradila je razdjelnike topline, zanimljivo je usporediti njihovu količinu isporučene toplinske energije za grijanje. zgrada B ima za 3,1 % veću površinu od zgrade C, ali manju priključnu snagu za 5,3 %, odnosno za 6,9 % nakon provedene energetske obnove.

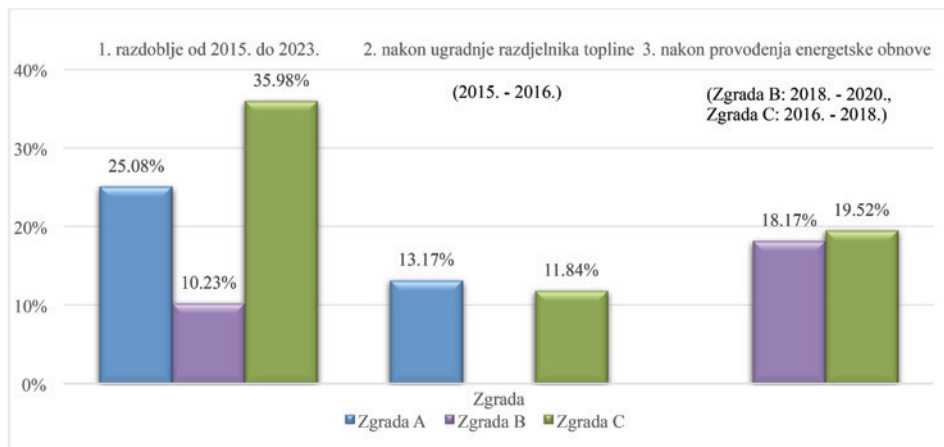
Grafički prikaz 6. Omjer ukupno isporučene toplinske energije zgradi C u odnosu na zgradu B u razdoblju od 2015. do 2023. godine



Izvor: izrada autora na temelju podataka HEP-TOPLINARSTVA d.o.o. (preuzeto iz Marelja, 2024)

Crvenom bojom na liniji označene su dvije godine za zgradu C, 2016. kada su razdjelnici topline implementirani u obračun toplinske energije te 2018. koja označava razdoblje nakon provedene energetske obnove. Zelenom bojom na liniji označena je 2020. godina koja označava razdoblje nakon provedene energetske obnove za zgradu B. Godine 2015. zgradi C isporučeno je 13,94 % manje toplinske energije za grijanje u odnosu na zgradu B. U 2016. godini zgrada C implementira razdjelnike topline u obračun te joj je iste godine isporučeno 37,43 % manje toplinske energije u odnosu na zgradu B. Trend manje isporučene toplinske energije zgradi C nastavlja se i u idućim godinama te kulminira 2018. kada je zgradi C, nakon provođenja energetske obnove, isporučeno 44,91 % manje toplinske energije nego zgradi B. Godine 2020. završava energetska obnova zgrade B, a iako se razlika u količini isporučene toplinske energije smanjila, zgradi C je i u razdoblju od 2020. do 2023. godine isporučeno prosječno 32 % manje toplinske energije u odnosu na zgradu B, što nedvojbeno pokazuje efektivnost razdjelnika topline.

Grafički prikaz 7. Uštede isporučene toplinske energije za grijanje prostora u zgradama obuhvaćenim studijom slučaja u razdoblju od 2015. do 2023. godine



Izvor: izrada autora na temelju podataka HEP-TOPLINARSTVA d.o.o. (preuzeto iz Marelja, 2024)

Ostvarene uštede toplinske energije u analiziranim zgradama obuhvaćenim studijom slučaja prikazane su u Grafičkom prikazu 8. U prvom dijelu grafičkog prikaza iskazane su ukupne uštede isporučene toplinske energije za grijanje prostora u razdoblju od 2015. do 2023. godine. U promatranom razdoblju količina isporučene toplinske energije za grijanje prostora zgradi A smanjila se za 25,08 % s prosječnom godišnjom stopom pada od 2,89 % dok se u istom razdoblju količina isporučene toplinske energije za grijanje prostora zgradi B smanjila za 10,23 % s prosječnom godišnjom stopom pada od 0,69 %. Zgrada C je u istom razdoblju ostvarila uštedu isporučene toplinske energije za grijanje prostora od 35,98 % s prosječnom godišnjom stopom pada od 4,46 %. U drugom dijelu grafičkog prikaza vidljivi su efekti ugradnje razdjelnika topline te su iskazane uštede toplinske energije za grijanje prostora za zgradu A i zgradu C. Budući da su obje zgrade razdjelnike topline implementirale u obračun toplinske energije početkom 2016. godine, promatra se razdoblje od 2015. do 2016. Zgrada A ostvarila je 13,17 % uštede u promatranom razdoblju, a zgrada C ostvarila je uštedu od 11,84 %. Treći dio grafičkog prikaza odnosi se na uštedu isporučene toplinske energije nakon provedene energetske obnove za zgradu B i zgradu C. To je iskazano tako što su uzeti u obzir podaci o isporučenoj toplinskoj energiji za grijanje u godini nakon provedene energetske

obnove koji su potom stavljeni u odnos s isporučenom toplinskom energije za grijanje u godini kada energetska obnova još nije započela. S obzirom na to da je za zgradu B nova termoenergetska suglasnost izdana od strane HEP-TOPLINARSTVA d.o.o. u prosincu 2020., analizirana je ušteda energije u razdoblju od 2018. do 2020., iako su efekti energetske obnove bili vidljivi već 2019. kada su radovi na zgradi još bili u tijeku. Sukladno navedenom, zgradi B je 2020. isporučeno 18,17 % manje toplinske energije za grijanje u odnosu na 2018. godinu. Nadalje, zgrada C je energetske obnovu završila 2017., a nova termoenergetska suglasnost izdana je od strane HEP-TOPLINARSTVA d.o.o. u travnju 2018. godine. Shodno tome, za zgradu C promatrano je razdoblje od 2016. do 2018. godine. Tako je zgradi C 2018. isporučeno 19,52 % manje toplinske energije za grijanje nego što je to bilo 2016. godine.

Sukladno svemu prikazanom, evidentno je da je zgrada C kombinacijom ugradnje razdjelnika topline i provedenom energetske obnovom zgrade ostvarila najveće uštede toplinske energije. Također, iako zgrada A nije provela energetske obnovu, ugradnjom razdjelnika topline ostvarila je značajnu uštedu toplinske energije. Zgrada B je nakon provedene energetske obnove, iako ne značajnu, ipak ostvarila određenu uštedu toplinske energije. Pretpostavka je da bi njezina ušteda toplinske energije uz ugrađene razdjelnike topline ili ugrađena zasebna mjerila bila na puno većoj razini.

5. ZAKLJUČAK

Problem na području EU-a jest velik fond zgrada starije gradnje koje imaju nisku razinu energetske učinkovitosti i troše značajnu količinu energije. Sve veći broj takvih zgrada ulazi u proces energetske obnove prvenstveno kako bi smanjili potrošnju energije, ostvarili financijske uštede i povećali razinu energetske učinkovitosti.

Osim provođenja energetske obnove, u koju najčešće ulazi poboljšanje toplinske ovojnice zgrade, preporučuje se ugradnja razdjelnika topline. Razdjelnici topline trebaju potaknuti racionalnije korištenje energije od strane građana, dok njihova isplativost ovisi o velikom broju faktora. Bez odgovornog ponašanja građana, razdjelnici topline sami po sebi ne garantiraju uštedu energije. Nepobitna činjenica jest da je ugradnjom razdjelnika topline ostvarena ušteda toplinske energije u višestambenim zgradama i to za čak 15 % do 30 % u odnosu na razdoblje prije ugradnje. Upitno je je li to realan pokazatelj s obzirom na to da se dosta građana boji grijati zbog straha od visokih iznosa računa za isporučenu toplinsku energiju te umjesto centralne toplinske energije

koriste klime i grijalice na struju ili neke prostorije u prostoru ne griju uopće, zbog čega dolazi do drugih problema kao što je pojava vlage.

Analiza isporučene ogrjevne topline i broja krajnjih kupaca u Zagrebu u razdoblju od 2014. do 2022. prikazala je da je priključenje novih krajnjih kupaca kompenziralo utjecaj mjera energetske učinkovitosti. Također, rezultati studije slučaja u kojoj je analizirana količina isporučene toplinske energije za grijanje u razdoblju od 2015. do 2023. godine u trima zgradama na području grada Zagreba koje su provele različite mjere energetske učinkovitosti, dokazali su sinergijski učinak više mjera energetske učinkovitosti. Najveću uštedu toplinske energije nedvojbeno je ostvarila zgrada koja je ugradila razdjelnike topline te potom provela i energetska obnovu.

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THE ROLE OF GREEN EMPLOYEE PERKS AND BENEFITS IN ENCOURAGING ENVIRONMENTALLY FRIENDLY BEHAVIOUR

Maja KLINDZIC*

The ever-growing and pressing problems around the globe – including, but not limited to climate, air and water pollution – are prompting businesses to incorporate sustainable practises into their daily operations and take a more active role in preventing further environmental damage. Furthermore, changes in the structure of the labour market, which is now dominated by millennials and members of Generation Z who are known for their unique values and attitudes towards environmental protection and social awareness, give employers an additional incentive to adapt their human resource management (HRM) practises to these values. In this context, HRM activities serve to attract, motivate and retain a green workforce. One set of specific activities aimed at aligning the values of the organisation and the individual through monetary incentives is the activity of rewards and benefits. Analysis of the available studies shows that of all the areas of Green HRM (GHRM), the area of green rewards and benefits is one of the least utilised and researched. Within this specific area, green benefits are particularly under-researched, despite being a highly valued recruitment and retention tool today. This study, therefore, attempts to fill the aforementioned gap through both secondary and primary research. Specifically, all publicly available sources on green benefits and privileges were first analysed and 22 different practises were identified. Primary research was then conducted by means of a questionnaire on a sample of 248 of the youngest members of the labour market. The survey analysed the respondents' preferences for the 22 green benefits mentioned

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above. The research showed: (1) that respondents perceived most green perks and benefits as having above average attractiveness; (2) that among these practises, green commuter benefits and practises related to work-life balance, i.e. flexible working arrangements and days off, stood out; (3) that the least desirable practise was the “give what you earn” scheme; and finally (4) several significant differences in attractiveness perceptions were found in relation to gender and nationality. As it has become imperative that business organisations take a more active role in promoting environmentally friendly behaviour as a corporate value, promoting awareness among their employees about the importance of their personal contribution to the preservation of the environment should be one of the most important HR activities in this regard. The results of this study can shed light on how to achieve the above goal, as employee benefits are known to attract and retain talent.

Keywords: *pro-environmental behaviour, Green HRM, green employee benefits, sustainability, employee values*

JEL classification: *J30, J33, M10, M12, M52*

INTRODUCTION

Awareness of the importance of environmental issues is now widespread throughout the world, therefore business organisations are progressively trying to focus their activities on reducing their own negative impact on the environment. One of the goals, or even values, often found in the organisations' missions is corporate social responsibility, of which environmental responsibility is an important pillar. Organisations achieve this through the application of various green measures, which can now be found in almost every activity of the organisations (Galetić et al., 2008), and aim to encourage employees to adopt environmentally friendly or eco-friendly behaviour. Environmentally Friendly Behaviour (EFB) is a complex concept that remains difficult to define (Banwo & Du, 2019), but mostly refers to actions aimed at preventing environmental damage and/or protecting the environment in both public and private spheres (e.g. Steg & Vlek, 2009).

As corporate environmental responsibility is increasingly seen as a strategic pillar or goal of organisations, it naturally permeates the entire organisation and is addressed by everyone in the company, including line managers and HR, who develop and implement Green HR Management (GHRM) prac-

tises. In addition to activities such as green recruitment, green performance appraisal or green training and development, GHRM activities to promote green behaviour in the workplace also refer to green reward management (see e.g. Ahmad, 2015). This is because rewards can link the interests of the organisation with the interests of employees, as they focus employees' attention on the most important aspects of their work and motivate them to maximise their efforts (Jackson et al., 2011). It is generally accepted that in order to improve the environmental effectiveness of organisations, it is important to implement a reward system that includes a variety of rewards – of both financial and non-financial nature (Renwick et al., 2013).

In terms of financial rewards, there are direct rewards paid to employees in cash for work performed, such as base salary, bonuses for individual or group performance, and through shares. On the other hand, non-financial rewards, or perks and benefits, are used by employers to show that they care about the personal needs of their employees or because they want to offer an attractive and competitive total compensation package (Galetić & Klindžić, 2020). In fact, research has shown that companies today need to tailor their benefits package to the expectations of the youngest generation of employees (Sidorcuka & Chesnovicka, 2017). There is increasing competition for highly qualified workers, so it is especially important that business organisations understand what the youngest generation of employees expects from them (Hafid, 2023). As this generation is described as the most socially oriented and educated generation that actively wants to make a difference (Hafid, 2023), employers should look for ways to align employees' personal and organisational values.

Although there is a considerable number of studies addressing the use of GHRM practises in general and a slightly smaller number of sources analysing the use and impact of various green reward practises, there are *de facto* no studies that provide a systematic overview of the possible green perks and benefits practises for employees. The main and additional research questions of this thesis are therefore the following:

- RQ1 – What options are available to employers who wish to promote EFB through perks and benefits?
- RQ2 – Which of the systematised green perks and benefits are perceived as most attractive by members of the youngest generation cohort?

LITERATURE REVIEW

GREEN ECONOMY AND ENVIRONMENTALLY FRIENDLY BEHAVIOUR

The field of green economy gained prominence in the early 1990s when the United Nations formally adopted the concept of sustainable development at the Rio de Janeiro conference, and 20 years later defined “green economy” as a way to achieve this goal (Loiseau et al., 2016). As the problems of environmental protection become more serious and include, for example, climate change and the pollution of air, water and soil on a global scale (Osbaldeston & Schott, 2012), companies are increasingly taking responsibility for their own behaviour and are therefore taking systematic, socially responsible measures. The promotion of environmentally responsible behaviour stands out among these measures and is commonly referred to as environmentally friendly behaviour (EFB) and pro-environmental behaviour, among others. Again, this is a complex concept, generally defined as actions taken to prevent environmental damage and/or protect the environment in the public and private sectors (Steg & Vlek, 2009). Scientifically, the most studied EFB is recycling, but water and energy conservation are also important (Osbaldeston & Schott, 2012). Indeed, employees in the workplace are the main driving force behind a successful implementation of environmental initiatives (Banwo & Du, 2019) and can demonstrate green organisational behaviour in a variety of environmentally conscious ways. Although scholars from a variety of fields – from marketing to supply chains – are actively analysing how management practises in these areas can contribute to the achievement of environmental goals (Jackson et al., 2011), including EFB, the success of any efforts in this area is mostly based on human resource management (Hooi et al., 2022).

THE ROLE OF GREEN HUMAN RESOURCE MANAGEMENT PRACTICES IN ENCOURAGING EFB IN THE WORKPLACE

Green Human Resource Management (GHRM) practises are referred to as a philosophy or a plan that helps to create a green workforce that can understand and appreciate a green culture in the organisation (Ahmad, 2015, p. 1). This concept is described in the literature as an innovative people management approach aimed at improving environmental efforts such as waste reduction and conservation of resource use, as well as economic well-being as an incentive for employees to behave in an environmentally friendly manner at work

(Obeidat et al., 2023). The HR department is the backbone of these efforts, as it plays a key role in aligning the corporate philosophy with the values and behaviour of employees (Hooi et al., 2022), which is why GHRM is becoming an important business strategy for major organisations where HR departments play an active role in the greening of offices (Ahmad, 2015).

Organisations can achieve better environmental performance through Green Human Resource Management (GHRM) core activities such as “green recruitment and selection”, “green training”, “green performance appraisal” and “green compensation and benefits” (see e.g. Ahmad et al., 2015; Jackson et al., 2011; Renwick et al., 2013). Training and development are the most studied practises in this context in the literature, with employee rewards and motivation coming second (Pham et al., 2020). Reward management practises serve to align the interests of the organisation with the interests of the employees, as they focus employees’ attention on the most important aspects of their work and motivate them to maximise their efforts (Jackson et al., 2011). In fact, Jackson and Seo (2010) believe that incentives and rewards align employee performance more closely with organisational goals than other HRM practises. Due to the difficulty of accurately and fairly assessing EFB and performance, creating appropriate monetary incentives can be a challenge for HR professionals and supervisors (Fernandez et al., 2003). Therefore, many scholars suggest that non-financial rewards, i.e. perks and benefits, could play a greater role in encouraging voluntary pro-environmental behaviour (e.g. Saed et al., 2018).

GREEN PERKS AND BENEFITS RELATED TO THE PROMOTION OF EFB IN THE WORKPLACE

Perks and benefits as an indirect salary element have an important impact on the competitiveness of employers, as it has been shown that the younger generation of employees in particular are increasingly looking for a variety of benefits and privileges when choosing their potential employer. This is important for employers because, on the one hand, they can use them to significantly improve their prospects of attracting and retaining employees in a tight labour market (Galetić & Klindžić, 2020). On the other hand, employee benefits have been shown to open significant savings opportunities for companies in a difficult economic situation – both by offering benefits that are tax-deductible and by introducing flexible benefit programmes (e.g. cafeteria benefits) for employees (Jackson et al., 2018). However, employers should pay attention to different

types of benefits, as it has been shown that employees often underestimate this type of material compensation and take it “for granted”.

There are various classifications of favours and advantages in the literature, of which those based on content predominate. According to the content criterion, benefits are categorised according to the basic needs they satisfy. In this context, three groups of benefits are distinguished: (1) pension, health and security benefits, (2) benefits for time off work, and (3) various services. Green aspects of these indirect material rewards have been mentioned in the literature and include, for example, paid vacations, gift vouchers or the use of bicycles and a less polluting vehicle fleet (e.g. Ahmad 2015; Saed et al., 2018; Tang et al., 2018). A more comprehensive overview of green perks and benefits that takes into account the content-based approach to benefit analysis mentioned above can be found in Table 1.

Table 1. Green perks and benefits clusters with regard to their content

Element	Sub-element	Main practices
Pension, health and security benefits	Paying contributions to green investment/pension funds	Payment or subsidisation of contributions to green funds that invest in green and/or socially responsible companies.
Time off work benefits	Extra days off work for low carbon footprint vacation	Extra days can be granted for using green transport and travel, especially when going on vacation (e.g. traveling by train instead of airplane).
Services-related benefits	Green commuting benefits	Transport and commuting benefits for employees, who can be encouraged to reduce their carbon footprint and develop a greater awareness of environmental protection (e.g. by using public transport or cycling to work).
	Flexi-place	Option of either full remote work or hybrid work to commute less or not waste energy (utilities).
	Other perks and services	It can include, for example, (1) food-related benefits – offering food in the workplace that is sourced from local family business; offering organic food options; (2) other benefits (discounts on environmentally-friendly products)

Based on: Klindžić (2024)

Despite the systematic approach outlined in Table 1, the literature still lacks a detailed account of the practises that can be used in organisations to

encourage employees to engage in EFB. Therefore, in the continuation of the paper, this element of reward will be addressed in more detail, and secondary research will be conducted to gather as much information as possible on the motivational practises for EFB through green benefits (RQ1). Subsequently, the perceived attractiveness of the identified green benefits will be analysed on a sample of members of the youngest generation of employees – Generation Z (RQ2).

RESEARCH METHODS

RESEARCH INSTRUMENT

A questionnaire was used to test the attractiveness of green benefits and perks. First, it was necessary to conduct secondary research from various academic and practitioner sources, based on which a detailed list of practises that can be used in the area of indirect material rewards to promote green behaviour could be compiled. This is because, although the field of green human resource management has experienced a great upsurge in the last decade, there is no source that systematically lists the options available to employers and/or researchers who want to apply or explore green practises not only in the area of benefits and perks, but also green compensation in general (see e.g. Klindžić, 2024). In order to collect secondary data on the existing practices of green benefits, the Google Scholar database was searched using the keywords “green compensation”, “green rewards”, “green compensation and benefits”, “green perks and benefits”. As these are practises that form one of the pillars of human resource management, the keywords “green human resource management” were also searched. As many of the papers mentioned did not contain specific practises, but were only addressed “in principle”, the practise-oriented websites of various consulting companies that offer services for the implementation of green compensations and benefits were also analysed. Secondary research conducted on more than 30 different sources resulted in a list of 22 practises in the field of green benefits. In the questionnaire, this is the central part of the instrument, where respondents were asked to rate the attractiveness of each of the listed 22 practises on a 5-point Likert scale (1 – not at all attractive, 5 – completely attractive). In addition to the green perks, the questionnaire contained only two socio-demographic questions of a binary nature – one related to gender and the other to national origin.

SAMPLE AND DATA COLLECTION PROCEDURE

The attractiveness of green perks and benefits was tested on a sample of students from the Faculty of Economics and Business in Zagreb. For the study purposes, questionnaires were distributed personally to students during lectures, in courses related to management and compensation management. The students were participants of very different educational programmes – university and professional, Croatian and English, and in different years of study – third, fourth and fifth. In addition, the data was collected at different time intervals in the period from December 2023 to November 2024. The final sample consists of 248 respondents, with 6 questionnaires discarded due to identified patterns in the allocation of marks or incomplete responses. The independent characteristics of the study participants are listed in Table 2. The sample is dominated by both women and Croatian students. The proportion of students enrolled in the integrated Bachelor/Master programme is almost equal to the proportion of students enrolled in the Bachelor-only programme, as is the proportion of students enrolled in the Croatian and English language programmes. Two thirds of the participants are enrolled in the third year of the programme, i.e. they completed the questionnaire during lectures in the management course.

DATA ANALYSIS METHODS

The data were analysed using the IBM SPSS 27.0 software. The methods used to analyse the data include both descriptive statistics (measures of centrality and variability) and inferential statistics (Mann-Whitney U test). The results are presented in tables and cross-tabulations in the following section.

Table 2. Independent characteristics of study participants

Sample characteristic		Data distribution	
		f	p
Gender	Men	94	37.90%
	Women	154	62.10%
Origin	Croatian	154	62.10%
	International	93	37.50%
Study programme by enrolment type	University – Integrated Bachelor and Master	112	45.16%
	University – Bachelor	105	42.34%
	University – Master	19	7.66%
	Professional – Master	12	4.84%
Study programme by language of teaching	Croatian-taught	124	50.00%
	English-taught	124	50.00%
Year of study	Third	168	67.74%
	Fourth	49	19.76%
	Fifth	31	12.50%
Course	Management (Croatian)	63	25.40%
	Management (English)	105	42.34%
	Compensation Management (Croatian)	49	19.76%
	Compensation Management (English)	19	7.66%
	Reward Management in SMEs (Croatian)	12	4.84%

RESEARCH RESULTS AND DISCUSSION

The descriptive analysis of the perceived attractiveness of green perks and benefits is presented in Table 3 and contains information on the centrality of the data, i.e. mean (AM), median (Me) and mode (Mo), as well as variability, i.e. standard deviation (SD) and coefficient of variation (CV).

Table 3. Descriptive statistics of attractiveness assigned to different green perks and benefits

Green perks and benefits	AM	Me	Mo	SD	CV
Providing vegetarian and/or organic lunch and snacks options.	3.02	3.00	3.00	1.37	45.36
Providing lunch and snacks options sourced from local businesses .	4.02	4.00	5.00	0.94	23.38
Providing companies' own garden kept freely by interested employees for growing food.	3.14	3.00	3.00	1.21	38.53
Bike-to-work scheme with a classical bike (company finances partly or completely the bike purchase or rent).	3.32	3.00	4.00	1.29	38.85
Bike-to-work scheme with an electrical bike (company finances partly or completely the bike purchase or rent).	3.55	4.00	4.00	1.18	33.24
Public transport costs covered (company finances a monthly or annual ticket for railway, tram or bus transport).	4.35	5.00	5.00	1.01	23.22
Electric car subsidy (company finances the purchase at least in some part).	4.02	4.00	5.00	1.10	27.36
Car-sharing or car-pooling (the employer encourages several employees to share one car and subsidizes the cost of fuel).	3.28	3.00	3.00	1.17	35.37
Company shuttle service (e.g. a corporate van transporting employees on a regular basis from home to work, and vice versa).	3.72	4.00	4.00	1.16	31.18
Walk-to-work scheme (usually monitored through an app, employees get symbolic awards for reaching goals in terms of miles/kilometres walked).	3.14	3.00	3.00	1.24	39.39
Encouraging hybrid work (combination of office and work from home) or telecommuting to reduce commuting costs.	4.45	5.00	5.00	0.92	20.67
A " climate budget " to help employees cover the costs of home insulation, solar panels or a heat pump.	4.07	4.00	5.00	1.04	25.55
Relocation subsidies – company covers the cost of moving furniture for employees who choose to find housing options closer to work.	4.02	4.00	5.00	1.08	26.86
Carbon-reducing subsidies – company provides discounts for more energy-efficient products, e.g. household composting containers, smart thermostats.	3.48	4.00	4.00	1.21	34.77

Green perks and benefits	AM	Me	Mo	SD	CV
Annual gift vouchers for running shoes at local sports shops to promote a culture of walking to work.	3.66	4.00	5.00	1.20	32.79
Give As You Earn schemes – providing the option of donating a symbolic part of the salary to a good cause.	2.89	3.00	3.00	1.23	42.56
Support a tree planting charity .	3.44	3.00	3.00	1.20	34.88
“Grow-your-own” workshops (hands-on programme focused on teaching how to cultivate own plants, emphasizing gardening, sustainability, and self-sufficiency).	3.11	3.00	3.00	1.21	38.90
Green gym subsidy (improving people’s health and well-being through participation in nature conservation activities).	3.73	4.00	5.00	1.15	30.83
Payment or subsidisation of contributions to green investment or pension funds (investments in companies that are considered socially conscious or directly promote environmental responsibility).	3.35	3.00	3.00	1.14	34.03
Paid days off for environment-related volunteer work .	4.15	4.00	5.00	1.06	25.54
Low-carbon holiday travel perk – extra days of holiday in exchange for taking the train instead of flying.	3.81	4.00	5.00	1.20	31.50

Out of the 22 green perks and benefits researched, 12 were found to be above average attractive to study participants. Among them, three practices particularly stand out: hybrid work or work from home (AM=4.45, Me=5, Mo=5), public transport costs covered by the employer (AM=4.55, Me=5, Mo=5) and paid days off work for volunteering (AM=4.15, Me=4, Mo=5).

Hybrid work/work from home is the most attractive of the green benefits examined in this study, which is in some ways the expected outcome that can be explained in at least three ways. In addition to the opportunity for employees to save time and other resources by no longer having to travel to work, significant work-life balance benefits can also be realised (Klindžić & Huljić, 2024). This is because the younger generation of employees has different values and attitudes towards work, so that non-work responsibilities – family, volunteering, etc. – are seen as at least as important, if not more important, than work-related tasks. Flexible forms of work make it easier to reconcile work and non-work responsibilities. Finally, in terms of job characteristics, such arrangements provide employees with a degree of control or autonomy

over working hours and/or location, which has been shown to be one of the most important characteristics of the workplace, leading to a greater sense of responsibility for work outcomes. By offering this type of flexible working, employers can also realise certain benefits for themselves. Indeed, research has confirmed that perceived provision of flexible working hours and the option to work remotely is significantly negatively related to the intention to leave the organisation among the youngest employees, i.e. the 25-34 year-olds (Masso et al., 2024). In addition, research has confirmed a positive impact on other individual and organisational outcomes, including health, absenteeism, turnover, profitability and service quality (Klindžić & Marić, 2019; Shifrin & Michel, 2021).

Employer coverage of public transport costs is at the top of the respondents' list of perceived green benefits, and is probably most closely linked to the environmental values that the younger generation aspires to. In the attempt to tackle today's climate and development challenges, public transport is one of the best and most cost-effective solutions, as it can reduce greenhouse gas emissions per kilometre by up to two-thirds compared to private vehicles (Welle et al., 2023). According to the UN climate report, switching to public transport is not only the "key" to addressing climate change, but better access to reliable public transport also brings important benefits to the society, such as better access to jobs or education (Welle et al., 2023). Another valuable effect of using public transport that should not be overlooked is the cost efficiency gained and the reduced financial burden (e.g. Green City Times, n.d.) compared to using a personal vehicle, which may be more important for the members of Generation Z than for other cohorts given their career stage and the need to create financial security. The positive effects of using public transport also include less stress due to less traffic congestion and more physical activity, as well as more time to relax during the journey (Green City Times, n.d.).

Paid days off for environment-related volunteering are highly favoured by the study participants. It has been shown that traditional volunteering has become less altruistic and more self-orientated (McLennan, 2020). This is particularly pronounced among the members of this generation, whose motivation is now to obtain learning opportunities and career advantages, while values and self-esteem play a slightly lesser role (Cho et al., 2023). Regardless of the motivation for volunteering, members of Generation Z certainly value additional paid holidays more, as this is in line with the attitudes towards work and life described earlier, where they place the balance between these two segments significantly high on the list of priorities.

The common interpretation of the three most attractive practises among the respondents stems from the merging of two important pillars of the new “triple bottom line” approach to employer success – the one related to people and the one related to the environment, but ultimately also the third – profit. In other words, the emergence of Green HRM encompasses the improvement of social (e.g. work-life balance through flexi-place practises) and economic well-being (i.e. sustainable profits), as well as awareness of environmental concerns (e.g. less waste or lower carbon footprint through green commuting options) (see also Saed et al., 2018).

The lower and middle part of the list of green benefits should also be mentioned. Neutral attractiveness was found for vegetarian and organic food options offered at work (AM=2.89, Me=3, Mo=3), home-growing workshops (AM=3.02, Me=3, Mo=3) and company garden (AM=3.14, Me=3, Mo=3), all of which belong to the groups of benefits related to food preferences and involvement in preparing or growing food. The least attractive green benefit was the “Give As You Earn” programme (AM=2.89, Me=3, Mo=3), also known as a salary sacrifice programme or payroll giving programme, especially popular in the UK. This can be attributed to the aforementioned fact that people want to achieve financial security in the early stages of their career and are, therefore, not prepared to sacrifice part of their salary for environmental concerns.

Finally, an analysis was conducted to identify the possible differences in the perceived attractiveness of green benefits in relation to the gender and origin of the participants. The results of the Mann-Whitney U-tests are shown in Table 4. There were 11 statistically significant differences in the perceived attractiveness of green perks and benefits in relation to gender and 9 differences in relation to origin, while for 6 perks and benefits differences were found in relation to both individual characteristics.

Table 4. Statistical differences in the perception of attractiveness of green perks and benefits with regard to gender and origin

Green perks and benefits	Gender		Origin	
	MWU	p	MWU	p
Vegetarian and/or organic lunch and snacks	5622.000	0.003		
Lunch and snacks sourced from local businesses	5780.000	0.005	5867.000	0.012
Companies' own garden kept freely by employees	5878.000	0.021	6013.000	0.049
Public transport costs covered	5926.000	0.007	6149.500	0.045
Encouraging hybrid work or telecommuting	6000.000	0.006	6132.000	0.023
A " climate budget " to help cover the costs of home insulation, solar panels or a heat pump	5509.000	0.001		
Relocation subsidies			5609.000	0.004
Carbon-reducing subsidies	5425.000	0.001		
Give As You Earn schemes			5668.000	0.007
Support a tree planting charity	5506.500	0.002	5782.000	0.014
" Grow-your-own " workshops	5808.500	0.014		
Green gym subsidy	6031.000	0.040		
Paid days off work for environment-related volunteer work	6164.000	0.047	5857.500	0.014
A low-carbon holiday travel perk			6065.500	0.036

Interestingly, all the differences found in terms of gender relate to women, who consistently assigned higher attractiveness scores to these 11 green perks and benefits. In other words, the women in this study appear to be more interested in green benefits than men, possibly indicating a greater interest in environmental issues in general. In terms of origin, only 2 of the 9 identified green benefits were consistently rated higher by international students, namely employer funding for public transport and benefits for low-carbon holidays. Although no detailed information is available on the origin of the students (most of them are from the EU), the results could generally be explained either by national cultural characteristics (e.g. if the participants come from cultures where owning a personal vehicle is not considered a value) or simply come from countries and urban areas where public transport is considered well organised, accessible and efficient.

CONCLUSION

As it has become imperative that organisations take a more active role in promoting EFB as a corporate value, promoting awareness among their employees about the importance of their personal contribution to the preservation of the environment should be one of the most important HR activities in this regard. Green benefits have a significant potential to promote EFB among younger generations of workers. Secondary research identified 22 green benefits for which 248 participants, students of Croatian and English business administration programmes at the Faculty of Economics in Zagreb, rated their perceived attractiveness. Although most practises were rated as above average in attractiveness, practises related to flexible workplaces, commuting by public transport and days off for volunteering stand out especially among Generation Z members. The above practises demonstrate the interdependence of the three pillars on which modern employers build their organisational performance – people, environment and profit. Compensation and benefits packages should be redesigned to meet the expectations and values of the youngest generation of employees.

This research is not without its *limitations*. The most recent Eurostudent study confirmed that own income from paid work during studies is the largest source of funding in terms of amount, and that the proportion of students pursuing student employment is increasing (Rimac, 2021), so it can be assumed that the majority of the students surveyed had some work experience. However, student work experience was not explicitly controlled for in the primary data collection phase, so this is the first limitation of the study. In addition, although the questionnaire only included a table of 22 green perks and benefits to assess attractiveness, it may have been too much effort for some respondents to read all the items and associated explanations. The cross-sectional nature of the study is also a potential limitation, as it could reflect the current moods of the participants. Finally, the quantitative nature of the study limited the possibility of gaining deeper insights into the topic at hand. In line with the aforementioned limitations of the present study, *future studies* should definitely aim to collect data on a sample of employees (excluding students) in order to investigate whether actual work experience is related to the perceptions of attractiveness of green perks and benefits among students and employees – not just for Generation Z, but for other generations as well. In addition, collecting qualitative data (via interviews) on why certain green benefits appear more attractive than others would add to the knowledge base on pro-environmental behaviour in the workplace and the specific ways to promote it.

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CHALLENGES IN IMPLEMENTING EUROPEAN GREEN DEAL IN ENERGY SECTOR AND GRID FLEXIBILITY IN CROATIA / IZAZOVI PROVEDBE EUROPSKOG ZELENOG PLANA NA PODRUČJU ENERGETIKE I FLEKSIBILNOST ELEKTROENERGETSKE MREŽE U HRVATSKOJ

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The European Union is undergoing a historic economic shift towards a low-carbon and carbon-neutral economy through an extensive package of laws, measures, and initiatives known as the European Green Deal. The aim is to achieve net-zero carbon dioxide emissions by 2050 across the EU. This plan has a significant transformative impact on all sectors of the economy, particularly on the energy sector, which has the highest percentage of total CO₂ emissions in the Union. The challenges of implementation are presented across four main areas of the energy sector and later analyzed in a comparative case study.

In the accelerated construction of new renewable energy production units, such as wind farms and photovoltaic plants, issues arise from the unpredictability of wind and sunlight, leading to either excessive or insufficient electricity production, unfavorable geographical distribution of production units, increased demand for system balancing, and quality supply problems for end customers.

Due to the construction of new renewable energy production units and the constant growth in consumption, existing transmission networks are increasingly overloaded. The development of new transmission capacities is slow and does not keep pace with the growth of new renewables. The construction process is burdened by numerous issues such as property rights, complicated legislation, slow bureaucracy, and more.

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One of the new hopes for energy transition is green hydrogen. Produced exclusively using renewable energy sources, it has great potential for direct use in decarbonizing various industries and for energy storage. However, systems involving green hydrogen require significant co-financing and face challenges such as the lack of a market for hydrogen, storage issues, and transport logistics.

New nuclear power plants will also be part of the new low-carbon energy system but must address significant delays in construction, budget overruns, and nuclear waste storage.

In Croatia, projects are currently underway that could provide flexibility to the electricity grid upon their completion. These include projects like battery storage systems, virtual power plants, and green hydrogen production and usage initiatives. Despite facing various challenges, all observed projects are progressing and contributing to enabling and implementing the green transition in Croatia.

All mentioned problems are solvable; for renewable energy sources, it will primarily be necessary to ensure parallel construction of flexibility systems for the electricity grid. Accelerating the development of electricity networks can only come from a pan-European consensus on removing bureaucratic barriers and decisively launching and financing such projects. The economy of green hydrogen is still emerging; its successful maturation will require both co-financing and significant further technological development to become more cost-effective. New nuclear power plants suffer from significant delays that greatly increase project costs. One potential solution could be relying on vertically integrated companies that could handle most tasks if fewer problems arise in mutual communication and coordination among different contractors.

Keywords: *European Green Deal, implementation of the European Green Deal, challenges for the European Green Deal, providing grid flexibility*

JEL classification: *Q42, Q41, O13*

U Europskoj uniji u tijeku je povijesni gospodarski zaokret ka niskougljičnom, odnosno ugljično neutralnom gospodarstvu kroz opsežan paket zakona, mjera i inicijativa nazvan Europski zeleni plan. Cilj mu je da do 2050. godine neto emisije ugljikova dioksida EU-a budu nula. Plan ima veliki transformativni učinak na sve grane gospodarstva, pa tako i na energetiku kao sektor s najvećim postotnim udjelom u ukupnim emisijama

CO₂ u Europskoj uniji. Izazovi provedbe predstavljeni su na četiri glavna područja energetike te kasnije i u komparativnoj analizi slučaja.

Kod ubrzanje izgradnje novih proizvodnih jedinica obnovljivih izvora energije poput vjetroelektrana i fotonaponskih elektrana javljaju se problemi prouzročeni nepredvidljivošću vjetra i osunčanosti, što dovodi do prevelike ili premale proizvodnje električne energije, nepovoljne geografske raspoređenosti samih proizvodnih jedinica, povećanja potrebe za uravnoteženjem sustava te problema kvalitete opskrbe krajnjih kupaca.

Zbog izgradnje novih proizvodnih jedinica obnovljive energije te konstantnog rasta potrošnje postojeće prijenosne mreže sve su češće preopterećene. Izgradnja novih prijenosnih kapaciteta odvija se usporeno i ne prati rast izgradnje novih obnovljivaca. Proces izgradnje opterećen je brojnim problemima poput imovinsko pravnih odnosa, komplicirane legislative, usporene birokracije i slično.

Jedna od novih nada energetike jest zeleni vodik. Kao vodik koji je proizveden isključivo korištenjem obnovljivih izvora energije ima veliki potencijal za direktno korištenje u dekarbonizaciji brojnih industrija, ali i u svrhu pohrane energije. Ipak, sustavi sa zelenim vodikom zahtijevaju značajno sufinanciranje, a postoje i problemi nepostojanja tržišta, pohrane vodika te njegova transporta.

Nove nuklearne elektrane također će biti dio novog niskougljičnog energetskog sustava, ali morat će se riješiti problemi velikih kašnjenja izgradnje, prekoračenja budžeta i pohrane nuklearnog otpada.

U Hrvatskoj se trenutačno provode projekti koji bi po svojoj realizaciji mogli pružati fleksibilnost elektroenergetskoj mreži. To su projekti poput baterijskih spremnika, virtualnih elektrana i projekata proizvodnje i korištenja zelenog vodika. Unatoč suočavanju s raznim izazovima, svi promatrani projekti idu naprijed dajući svoj doprinos u omogućavanju i provođenju zelene tranzicije u Hrvatskoj.

Svi su navedeni problemi rješivi, za obnovljive izvore energije u prvom redu bit će potrebno osigurati paralelnu izgradnju sustava fleksibilnosti elektroenergetske mreže. Ubrzanje izgradnje elektroenergetskih mreža može donijeti jedino sveeuropski konsenzus o ukidanju birokratskih prepreka te odlučno pokretanje i financiranje takvih projekata. Ekonomija zelenog vodika tek je u nastanku i za njezino uspješno sazrijevanje bit će nužno i sufinanciranje, ali i dodatni značajni razvoj tehnologije kako bi ona postala cjenovno pristupačnija. Nove nuklearne elektrane pate od značajnih kašnjenja, što iznimno poskupljuje projekte. Jedno od mogućih rješenja bilo bi oslanjanje na vertikalno integrirana poduzeća koja

bi mogla odraditi većinu posla ako bi što manje problema nastajalo u međusobnoj komunikaciji i usklađivanju hodograma različitih izvođača.

Ključne riječi: *Europski zeleni plan, provedba Europskog zelenog plana, izazovi za Europski zeleni plan, pružanje fleksibilnosti mreži*

JEL klasifikacija: *Q42, Q41, O13*

1. ZELENI PLAN I NJEGOVA PROVEDBA NA PODRUČJU ENERGETIKE

Europska svijest o potrebi zaštite okoliša postupno je rasla u drugoj polovici dvadesetog stoljeća, a dosegla je vrhunac donošenjem Europskog zelenog plana¹ 11. prosinca 2019. Njegov temeljni cilj jest dostizanje klimatske neutralnosti do 2050. godine. Pred Europskom unijom stoje brojni izazovi na mnogim područjima koji se međusobno isprepliću, tako su izazovi na području klime i okoliša usko povezani s gospodarskim pitanjima kao što su konkurentnost, prosperitet i održivost. Jedan je od ciljeva i da gospodarski rast ne bude ovisan o upotrebi resursa.

Energetski će subjekti u održivoj i zelenoj Europi trebati prvo smanjiti, a zatim i u potpunosti eliminirati svoje emisije štetnih i stakleničkih plinova. Izvori čiste i obnovljive energije bit će alat za odmak od energetske tehnologije koje su zagađivale. Na prvom mjestu po količini emisija stakleničkih plinova jest upotreba energije u gospodarskim sektorima s udjelom od 75 % u ukupnoj emisiji u EU-u (Europska komisija, 2019.). Kako bi se dosegli željeni klimatski ciljevi, nužna je dekarbonizacija i povećanje učinkovitosti energetskega sektora.

Kako sam Zeleni plan obuhvaća široko područje, u ovom radu fokus u identifikaciji i predstavljanju izazova u njegovoj provedbi pada na područje energetike. Čak i u samoj energetici, fokus je dalje sužen na samo četiri glavna područja koja su, po mišljenju autora ovog rada, najočitija te koje sam autor poznaje u dovoljnoj mjeri da može predstaviti neke izazove u njima. To su obnovljivi izvori energije kao glavni alat za zelenu tranziciju, nove prijenosne mreže koje će prenijeti novoproduciranu energiju do potrošača, zeleni vodik sa svojom dvostrukom ulogom u direktnoj dekarbonizaciji i pohrani energije te nove nuklearne elektrane kao pouzdani izvor bazne niskougljične energije.

¹ engl. *European Green Deal*

1.1. IZAZOVI INTEGRACIJE OBNOVLJIVIH IZVORA ENERGIJE

Fokus razmatranja u ovom radu jest na vjetroelektranama i fotonaponskim elektranama kao najzastupljenijim proizvodnim jedinicama obnovljive energije. Obnovljivi izvori energije razlikuju se od konvencionalnih u nekoliko ključnih karakteristika (International Energy Agency, 2014.): proizvodnja iz obnovljivih izvora energije (OIE) varira u ovisnosti o dostupnosti izvora energije, nepredvidljiva je, OIE proizvodne jedinice su modularne i male, ograničene su svojom geografskom lokacijom, uglavnom su asinkronog tipa (što utječe na upravljivost proizvodnje) i imaju niske kratkoročne troškove.

Nepredvidljivost vjetra i osunčanosti predstavlja jedan od najznačajnijih problema povezanih s obnovljivim izvorima energije (The EU-SYSFLEX Consortium, 2022.). Kod obnovljivih izvora energije, prekomjerna ili nedovoljna proizvodnja električne energije zbog njihove varijabilnosti može dovesti do problema s nedostatnim prijenosnim kapacitetima u mreži ili neadekvatnom opskrbom električnom energijom za krajnje korisnike.

OIE je logično graditi na područjima s najviše vjetra i sunca. U velikom broju slučajeva takve su lokacije udaljene od centara potrošnje, jer se radi o primjerice planinskim predjelima, otocima, a u novijim slučajevima i o odobalnim lokacijama (Europska komisija, 2022.A). S povećanjem udaljenosti koju električna energija mora prijeći od izvora do potrošača, rastu gubitci u elektroenergetskoj mreži.

Izazovi integracije OIE u elektroenergetski sustav mogu se svrstati u četiri glavne kategorije: kvaliteta isporučene energije u smislu neprekinutosti opskrbe i stabilnih napona i struja, problem tokova snage koji imaju utjecaj na lokalne ispade uslijed preopterećenja i s time povezanog oštećenja opreme te preusmjeravanja tokova i povećanih gubitaka u mreži, stabilnosti koju može narušiti činjenica da su proizvodne jedinice uglavnom asinkrone i modularne te u konačnici problemi balansiranja sustava koji se javljaju zbog neravnoteže između proizvedene energije i trenutne potrošnje.

Naravno, postoje različita rješenja za navedene probleme, koja se razlikuju po svojoj implementaciji, području primjene, složenosti i potencijalu za rješavanje problema. Ovisno o specifičnom problemu, mjere se mogu implementirati na centraliziranoj razini cijelog elektroenergetskog sustava ili distribuirano na određenom području mreže. Također, mogu se identificirati mjere koje utječu na fleksibilnost sustava pružajući dodatan izvor ili ponor radne energije, kao i mjere koje se odnose na poboljšanje prijenosne mreže (Sinsel, Riemke, & Hoffmann, 2020.).

Primjerice, uvođenje baterijskih spremnika energije može se provesti na obje razine sustava, pri čemu imaju bitno različite funkcije i koristi. Tako, na

primjer, instalacija baterije u kućanstvu ili manjim poslovnim prostorima ima funkciju optimizacije vlastite potrošnje i proizvodnje (Nano Energies, 2023.). S druge strane, kod velikih baterijskih sustava najčešće su u vlasništvu energetskih poduzeća i koriste se za pružanje pomoćnih usluga sustavu, kao što je balansiranje sustava kroz pružanje kratkoročnog izvora ili ponora energije (IE-ENERGY d.o.o., 2021.).

Snažan rast izgradnje postrojenja OIE u Europi i svijetu zahtijeva jasan, koordiniran i precizan odgovor na pitanje o zbrinjavanju opreme na kraju njezina životnog vijeka kada ona postaje opasan otpad. Također, postoje slučajevi u kojima se ispravna oprema zamjenjuje nakon određenog broja godina jer se na tržištu pojavljuju učinkovitije i jeftinije jedinice, što čini raniju zamjenu prvotno instalirane opreme isplativom (Mathur, Gregory, & Simons, 2020.).

1.2. IZAZOVI IZGRADNJE NOVIH PRIJENOSNIH MREŽA

Izgradnja novih vjetroelektrana i fotonaponskih elektrana predstavlja samo jedan dio onoga što je potrebno da bi energija proizvedena u njima došla do krajnjih potrošača. Drugi dio izazova leži u dogradnji postojeće i izgradnji nove električne mreže. To nije ni malen, ni jednostavan, ni jeftin zadatak. To je jasno vidljivo iz činjenice da je Europska komisija 18. listopada 2022. predstavila prijedlog Akcijskog plana EU-a za digitalizaciju energetskog sustava, u kojem se procjenjuje da će od 2020. do 2030. biti potrebno oko 584 milijarde eura ulaganja u elektroenergetsku infrastrukturu (Europska komisija, 2022.B).

Sam postupak izgradnje novih dalekovoda zahtjevan je proces koji obuhvaća izradu studija, ishođenje svih potrebnih dozvola, prihvaćanje projekata od strane javnosti, rješavanje imovinsko-pravnih pitanja, javnu nabavu i izgradnju. Može se zaključiti da je ovaj proces dugotrajan te zahtijeva temeljito predviđanje i planiranje budućih potreba korisnika sustava (Pavičić, 2022.).

Za europsku prijenosnu mrežu desetogodišnji plan izrađuje Europska mreža operatera prijenosnih sustava za električnu energiju², čiji su članovi operatori prijenosnih sustava u Europskoj uniji. Njihova je uloga osiguravanje sigurnosti umreženih električnih sustava, optimizacija njihova rada i razvoj umreženih tržišta električne energije (ENTSO-E, 2023.). Njihov aktualni desetogodišnji plan, nazvan TYNDP 2022³, koji je izrađen 2022. godine, kroz različite scenarije pruža prognozu potrebnog razvoja električne infrastrukture

² engl. *European Network of Transmission System Operators for Electricity* – ENTSO-E

³ engl. *Ten year network development plan* – TYNDP

u skladu s predviđenim potrebama europskog gospodarstva i energetike, uz poštivanje cilja dekarbonizacije.

Posredni ekonomski učinci provedbe ovih projekata jesu osiguranje potencijalnih 1,6 milijuna radnih mjesta, moguće investicije u ove projekte su oko 240 milijardi eura, europski BDP bi se mogao povećati za 100 milijardi eura i prihodi od poreza bi se mogli povećati za 45 milijardi eura (ENTSO-E, 2022.).

1.3. IZAZOVI UVOĐENJA ZELENOG VODIKA U ENERGETIKU

Na vodik otpada manje od 2 % ukupne europske potrošnje energije, a najveća je uporaba vodika u proizvodnji kemijskih proizvoda poput plastike i gnojiva. Većina vodika proizvodi se iz prirodnog plina (96 %), što rezultira značajnim emisijama ugljikova dioksida (Europska komisija, 2022.C).

Alternativni način proizvodnje vodika jest elektroliza vode, koja razdvaja vodu na vodik i kisik. Ako se elektrolizator napaja energijom proizvedenom iz obnovljivih izvora energije, tada govorimo o obnovljivom ili zelenom vodiku. Europa planira intenzivnu uporabu zelenog vodika kako bi postigla dekarbonizaciju u sektorima gdje druge alternative nisu izvedive ili su neisplative, kao što su sektori čelika, cementa, kemikalija i transport.

Jedan od glavnih razloga šireg neprihvatanja zelenog vodika od strane industrije jest njegova višestruko veća cijena u odnosu na vodik dobiven iz fosilnih goriva. Trenutačno, cijena vodika proizvedenog iz prirodnog plina iznosi oko 2 \$/kg (ovisno o cijeni prirodnog plina), dok se cijena zelenog vodika kreće oko 10 \$/kg (ovisno o tipu elektrolizatora i cijeni električne energije) (Schelling, 2023.). Cijena zelenog vodika od oko 2 €/kg i niže, kojom bi on postao konkurentan vodik iz fosilnih goriva, prema najavama iz Europske komisije očekuje se oko 2030. godine (EURACTIV.com with Reuters, 2021.).

Osim demonstracijskih postrojenja zelenog vodika gdje ekonomska isplativost proizvodnje vodika nije u prvom planu, jasno je da će se vodikove tehnologije i sama proizvodnja morati vrlo izdašno sufinancirati dok se u dovoljnoj mjeri ne ostvare dvije glavne pretpostavke: pad cijene električne energije uslijed znatnog upliva obnovljivaca te pad cijene opreme, u prvom redu samih elektrolizatora.

Ciljeve vezane za vodik za 2030. i 2050. godinu neće biti lako provesti. Jedan od najočitijih problema jest nepostojanje dovoljne potrošnje i istovremeno nepostojanje dovoljne proizvodnje niskougljičnog i obnovljivog vodika. Kada se razmatra proizvodnja vodika iz fosilnih izvora uz tehnologiju skladištenja ugljikova dioksida, cilj obnovljivosti nije postignut. U tom slučaju, mjere poput

banke vodika potiču povećanje potrošnje takvih goriva, što je suprotno ciljevima zelene tranzicije i plana REPowerEU, koji se, između ostalog, fokusira na smanjenje ovisnosti o ruskom plinu i plinu općenito (Hernandez, 2021.).

Trenutačna razina razvijenosti tehnologije i sustava za pohranu vodika još uvijek nije zadovoljavajuća s obzirom na kriterij tehničke i ekonomske isplativosti. Transport vodika suočava se s izazovima zbog problema s pohranom, zato što spremnici moraju biti pod visokim tlakom, što značajno povećava njihovu masu i smanjuje količinu vodika koja se može prevoziti, primjerice u autocisternama.

Današnji elektrolizatori vodika imaju učinkovitost koja se kreće od oko 60 % do oko 80 %, ovisno o tehnologiji samog elektrolizatora i stupnju opterećenja (International Energy Agency, 2019.). Iz proizvedenog vodika, električna energija može se dobiti kroz dva procesa: direktnim izgaranjem (ali uz nisku učinkovitost od 20 - 25 % (Hosseini & Butler, 2020.) uz ispuštanje dušikovih oksida) i upotrebom u vodikovim gorivnim ćelijama, čija je učinkovitost oko 60 - 80 %, pri čemu je voda jedini nusprodukt (Mekhilef, Rahman, & Safari, 2012.).

Pohrana vodika može se odvijati u različitim vremenskim razmacima: kratkom, srednjem i dugom roku. U kratkom roku, vodik se može koristiti za pružanje pomoćnih usluga elektroenergetskom sustavu putem elektrolizatora i gorivnih ćelija, čime se održava stabilnost napona i frekvencije (Tuinema, i dr., 2020.).

Vodik se može i direktno ubaciti u postojeću plinsku mrežu, ali do maksimalnog volumnog udjela od 15 % do 20 % (kod visokotlačnih plinovoda čak i niže) kako bi se izbjegla pojava krtosti⁴ željeza i čelika (od kojih su plinovodi napravljeni) zbog vodika (Quarton & Samsatli, 2018.).

1.4. IZAZOVI IZGRADNJE NOVIH NUKLEARNIH ELEKTRANA

Nuklearna energija nalazi se odmah iza hidroenergije po udjelu u proizvodnji električne energije iz niskougljičnih izvora. Nuklearne elektrane tijekom svoga rada gotovo uopće ne proizvode emisije stakleničkih plinova (Jawerth, 2020.). One se uglavnom koriste kao pouzdan izvor bazne energije te uglavnom rade na punom opterećenju. U budućnosti će biti sve više potrebe za većom fleksibilnosti i nuklearnih elektrana, stoga se novi projekti razrađuju imajući u vidu i taj zahtjev, a u projekte se ugrađuju i mogućnosti pružanja

⁴ engl. *hydrogen embrittlement*

neelektričnih usluga poput proizvodnje vodika, desalinizacije vode, industrijske topline, rafiniranja i proizvodnje sintetičkih plinova (Fisher, Constantin, & Liou, 2021.).

Donošenje odluke o izgradnji nuklearne elektrane ovisi o mnogim čimbenicima i općenito je jako zahtjevan i složen proces. Prva glavna prepreka koju treba premostiti jest negativna percepcija nuklearne tehnologije u javnosti. Ona najčešće proizlazi iz bojazni o radiološkim štetama koje mogu izazvati incidenti poput nesreća u Černobilu i Fukušimi. Također postoji i snažna percepcija straha od zračenja elektrana tijekom normalnog pogona elektrane. Još jedan velik problem vezan uz bojazan o štetnom učinku nuklearnih elektrana jest i neriješeno pitanje dugoročnog odlaganja istrošenog goriva i opreme, koje je najsmislenije rješavati združeno na međudržavnoj razini.

Jednom kad se odluči za projekt izgradnje nuklearne elektrane treba biti oprezan s procjenom duljine trajanja projekta. U pravilu su ovako složeni projekti podložni kašnjenjima, a to se naročito očituje kod projekata nuklearnih elektrana u nekoliko posljednjih dekada. Razlozi za kašnjenje projekata uključuju neažuriranje rasporeda dovršetka pojedinih faza projekta, greške u projektiranju, promjene opsega radnji, probleme s izvođačima, dobavljačima, probleme s financiranjem, krive procjene trajanja pojedinih etapa projekta, krive procjene potrebe za resursima poput radne snage, probleme s podrškom inženjerskog tima iz elektrane, potrebe za ponavljanjem radova zbog greški, odluka investitora, lošeg vremena i drugih (Alsharif & Karatas, 2016.).

U Europi se kao i u svijetu bilježe značajna kašnjenja projekata izgradnje nuklearnih elektrana od kojih su najpoznatiji slučajevi u Finskoj, Francuskoj i Ujedinjenom Kraljevstvu.

Novi reaktorski dizajn u vidu malih modularnih reaktora⁵ trenutačno se razvija i gradi u nekoliko zemalja. SMR reaktori su napredni nuklearni reaktori snage do 300 MWe po jedinici, što je otprilike trećina snage klasičnih velikih nuklearnih reaktora. Njihove su glavne prednosti, zbog kojih je razvijen ovakav dizajn, njihova mala veličina i modularnost.

Mala veličina omogućuje proizvodnju tih reaktora u tvornici te njihov transport na odabranu lokaciju i instalaciju, što bi trebalo smanjiti troškove izgradnje u usporedbi s klasičnim velikim reaktorima koji zahtijevaju prilagodbu svakoj pojedinoj lokaciji. Time se ostvaruju značajne uštede u troškovima i vremenu izgradnje. Modularnost omogućuje postupno povećanje broja jedinica na lokaciji kako raste potrošnja, a početna je investicija manja, što olakšava financiranje projekta. Važno je istaknuti da se modularnom izgradnjom

⁵ engl. *Small Modular Reactors* - SMR

omogućuje da prva jedinica krene u proizvodnju ranije zbog jednostavnije i brže izgradnje. To omogućuje ostvarivanje prihoda ranije tijekom projekta i olakšava financiranje sljedećih jedinica.

U usporedbi s klasičnim reaktorima, SMR reaktori imaju jednostavniji dizajn i sigurnosne se značajke više oslanjaju na pasivne mjere i karakteristike malih reaktora poput manje snage i nižih tlakova. SMR-ovi bi trebali puno lakše varirati svoje proizvodno opterećenje, što će biti od velike važnosti u budućim energetskim sustavima u kojima će dominirati obnovljivi izvori energije (IAEA, 2021.).

Unatoč istaknutim prednostima kao što je niži početni investicijski trošak, trenutni projekti malih modularnih reaktora suočeni su s velikim kašnjenjima i višom cijenom po instaliranom kilovatsatu u usporedbi s postojećim velikim reaktorima treće i treće plus generacije (Schneider, i dr., 2022.).

U vrijednosnom lancu izgradnje novih nuklearnih elektrana, proizvođači teških komponenata, poput reaktorske posude, parnih turbina i parogeneratora, igraju važnu ulogu. U svijetu je broj takvih proizvođača jako malen, a na njima se izrađuje i čitav niz drugih proizvoda, što dovodi do stvaranja svojevrsnog uskog grla u broju nuklearnih komponenti koje se mogu proizvesti u određenom razdoblju. (World Nuclear Association, 2021.)

Nivelirani trošak predstavlja ukupnu cijenu izgradnje i pogona elektrane tijekom njezina životnog vijeka, podijeljenu s ukupnom količinom proizvedene električne energije u tom razdoblju. Obično se izražava u novčanoj jedinici po megavatsatu, tipično u €/MWh ili \$/MWh. Analize (Lazard, 2021.) pokazuju da su se u SAD-u od 2009. do 2021. godine prosječni nivelirani troškovi bez subvencija značajno smanjili s 359 \$/MWh na 36 \$/MWh za velike fotonaponske elektrane, sa 135 \$/MWh na 38 \$/MWh za vjetroeletkrane te povećali sa 123 \$/MWh na 167 \$/MWh za nuklearne elektrane.

Slične odnose u niveliranim troškovima navodi i Međunarodna energetska agencija u svom putokazu ka ugljičnoj neutralnosti do 2050., gdje se za 2020. godinu navode prosječni nivelirani troškovi od 50 \$/MWh (SAD) i 55 \$/MWh (EU) za velike fotonaponske elektrane, 35 \$/MWh (SAD) i 55 \$/MWh (EU) za vjetroeletkrane na kopnu, 115 \$/MWh (SAD) i 75 \$/MWh (EU) za odobalne vjetroeletkrane te 105 \$/MWh (SAD) i 150 \$/MWh (EU) za nuklearne elektrane (International Energy Agency, 2021.).

2. KOMPARATIVNA ANALIZA STUDIJA SLUČAJA PROJEKATA ZA PRUŽANJE FLEKSIBILNOSTI ELEKTROENERGETSKOJ MREŽI

Uvođenjem sve više obnovljivih izvora energije na postojeće elektroenergetske mreže javlja se jaka potreba za njihovom prilagodbom novonastalim okolnostima. U zelenoj tranziciji već su se pojavili decentralizirani i manji proizvođači priključeni u distribucijskoj mreži, koji značajno mijenjaju tokove snaga i pojave u električnim mrežama, a bit će ih sve više. Kako bi se riješili neki od problema koje ove promjene izazivaju, pojavila se potreba za agregiranjem decentraliziranih proizvodnih izvora, zatim distribuirane upravljive potrošnje te jedinica za pohranu energije u svrhu pružanja dodatne fleksibilnosti elektroenergetskom sustavu, koja će biti sve potrebija (The EU-SYSFLEX Consortium, 2022.).

Zakon o tržištu električne energije (NN 111/2021) definira agregatora kao sudionika na tržištu koji se bavi agregiranjem. Agregiranje je definirano kao djelatnost koju obavlja fizička ili pravna osoba koja može kombinirati snagu i/ili iz mreže preuzetu električnu energiju više kupaca ili operatora skladišta energije ili snagu i/ili u mrežu predanu električnu energiju više proizvođača ili aktivnih kupaca ili operatora skladišta energije radi sudjelovanja na bilo kojem tržištu električne energije (Hrvatski sabor, 2021.).

U Hrvatskoj su se za sada istakla tri poduzeća koja nude usluge agregiranja, uglavnom ih predstavljajući kroz svoje virtualne elektrane. Minimalna snaga za pružanje fleksibilnosti koju zahtijevaju od korisnika iznosi 100 kW. To su KOER d.o.o., Nano Energies Hrvatska d.o.o. i IE-ENERGY d.o.o. Najizravniji i najjednostavniji koncept pohrane viškova energije te otpuštanja energije u razdobljima njezina manjka u sustavu predstavljaju veliki sustavi baterija. U Hrvatskoj takav projekt razvija poduzeće IE-ENERGY d.o.o.

Zeleni vodik ima jednu od glavnih uloga kao prijelazni nosilac energije između pojedinih energetske i kemijske procesa u energetske tranziciji. Partnerstvo za čisti vodik⁶ je 31. siječnja 2023. nastavno na inicijative sadržane u inicijativi REPowerEU odabralo devet projekata dolina vodika⁷, koji će se financirati s ukupno 105,4 milijuna eura. Partnerstvo za čisti vodik je javno privatno partnerstvo koje podupire aktivnosti istraživanja i inovacija u području tehnologije vodika u Europi, čije bi aktivnosti trebale rezultirati razvojem i integracijom vrijednosnog lanca zelenog vodika na područjima poput industrije, energetike i transporta (Europska unija, 2021.) (Clean Hydrogen Joint Undertaking, 2023.).

⁶ engl. *Clean Hydrogen Partnership*

⁷ engl. *Hydrogen Valleys*

Poduzeća ACI d.d. i Dilj d.o.o. u svojim projektima imaju predviđenu izgradnju elektrolizatorskog postrojenja koje ima mogućnosti pružanja fleksibilnosti elektroenergetskom sustavu proizvodeći zeleni vodik po konkurentnim cijenama u razdobljima kada energije ima previše u sustavu.

2.1. METODOLOGIJA ISTRAŽIVANJA

Ciljevi ovog rada su:

- C1: Identificirati potencijalne poteškoće u provedbi Plana na području energetike u Europskoj uniji i Republici Hrvatskoj, s ciljem prepoznavanja najkritičnijih aspekata provedbe Plana u energetskom sektoru te istaći važnost njihovih što bržih uklanjanja.
- C2: Analizirati ključne izvedbene elemente i izazove relevantnih energetskih projekata koji će doprinijeti provedbi Europskog zelenog plana u Hrvatskoj. To će se postići putem detaljnih studija slučaja koje će predstaviti iskustva hrvatskih poduzeća koja provode navedene projekte.

Nakon sakupljanja podataka iz svih izvora, provedena je analiza temeljena na njima te su teme u radu obrađene sukladno rezultatima te analize.

Kao metodologija koja se koristi za provedbu istraživanja u ovom radu odabrana je kvalitativna metodologija. Ona ima za cilj dublji uvid i razumijevanje istraživane problematike (Tkalac Verčić, Sinčić Ćorić, & Pološki Vokić, 2010.). Ovdje to konkretno znači da će se uz pomoć nje pokušati steći uvid u izazove s kojima se susreću poduzeća koja provode projekte pružanja fleksibilnosti elektroenergetskoj mreži u Hrvatskoj. Istraživanje se provodi u stvarnom okruženju, a samo istraživanje je opisno (metoda deskripcije) i temeljeno na induktivnom procesu zaključivanja.

Kvalitativna metodologija podrazumijeva istraživanje u stvarnim uvjetima, a uzorak se bira namjerno i svrsishodno jer se od njega očekuje da obiluje informacijama o predmetu istraživanja. Tako je fokus ovog istraživanja sužen na pet već spomenutih poduzeća. Podatci koji su podloga za studije slučaja prikupljali su se analizom dostupne dokumentacije, putem upitnika i polustrukturiranim intervjuima s projektnim menadžerima i ključnim dionicima iz poduzeća koja sudjeluju u provedbi projekata za pružanje fleksibilnosti elektroenergetskoj mreži u Hrvatskoj.

Upitnik koji se slao poduzećima imao je za cilj da se putem odgovora na trinaest pitanja dobije slika o trenutačnoj situaciji vezanoj uz provedbu projekata pružanja fleksibilnosti, odnosno izazova koji prate njihovu realizaciju.

Pitanja su grupirana u tri grupe: opći dio, trenutni izazovi provedbe projekta te pogleda u budućnost. Po primitku odgovora sa svakim ispitanikom je proveden i dodatni polustrukturirani intervju u kojem se još jednom prošlo kroz odgovore u upitniku i po potrebi ih se dodatno raspravilo.

Putem studije slučaja dobivamo opis i podatke iz prve ruke o promatranom problemu kroz blisku interakciju ispitanika i ispitivača. Sljedeći korak jest međusobna usporedba podataka iz studija slučaja putem komparativne analize. U raspravi su komparativnom analizom uspoređeni podatci iz svih četiriju studija slučaja, te su uz pomoć metoda deskripcije, indukcije, sinteze i generalizacije predstavljeni.

2.2. RASPRAVA

Istraživanje je provedeno u suradnji s ključnim osobama u svakom od četiriju promatranih poduzeća od kojih svaki obavlja vodeću ulogu u provedbi projekata koje u ovom radu razmatramo. Poduzeće Dilj d.o.o. provodi projekt uvođenja zelenog vodika u jedan od svojih pogona u sklopu kojega je predviđena izgradnja elektrolizatorskog postrojenja koje bi moglo pružati usluge uravnoteženja mreže. S druge strane, poduzeća KOER d.o.o. i Nano Energies Hrvatska d.o.o. bave se agregatorskom djelatnošću i po poslovnom modelu nemaju puno sličnosti s poduzećem Dilj d.o.o. Poduzeće IE-ENERGY d.o.o. kroz svoj projekt želi izgraditi baterijski sustav koji će direktno u suradnji s operatorom prijenosnog sustava uravnoteživati mrežu. Kao dodatnu djelatnost planiraju pružati i usluge agregiranja. Promatrana poduzeća razlikuju se u značajnoj mjeri u osnovnim poslovnim modelima te na iste izazove nemaju isti pogled.

Zelena tranzicija za promatrana poduzeća predstavlja različite stvari; za Dilj d.o.o. u prvom redu ona znači put ka smanjenju energetske ovisnosti i smanjenju emisija. Za preostala tri poduzeća ona je razlog i smisao zbog kojeg su uopće osnovana, jer sebe vide kao ključnu kariku koja će unaprijediti elektroenergetski sustav i olakšati samu tranziciju ublažavanjem problema koje njezina provedba donosi.

Projekti su u različitim fazama realizacije. Oba agregatorska poduzeća imaju dobro uhodane poslovne aktivnosti s razvijenim portfeljima. IE-ENERGY d.o.o. je u fazi izgradnje baterijskog postrojenja u trenutku pisanja ovog rada, dok je projekt poduzeća Dilj d.o.o. u pripremnoj fazi (zatvaranje tehničko tehnološkog rješenja i traženju potrebnih izvora sufinanciranja).

Financiranje realizacije projekta za agregatorska poduzeća ne predstavlja problem, što se može opravdati činjenicom da su kapitalne investicije u

pokretanju ovakvog poslovanja manje u odnosu na druga dva poduzeća. Za agregatore najznačajnije troškove predstavljaju razvoj softversko-hardverskog rješenja, trošak opreme koja se ugrađuje kod klijenta te trošak svakodnevnog poslovanja. Kod baterijskog i elektrolizatorskog postrojenja najveći i najznačajniji trošak jest samo postrojenje (baterije i elektrolizator) koje je u oba slučaja jako skupo. IE-ENERGY d.o.o. je uspio financijsku konstrukciju zatvoriti uz pomoć sufinanciranja u iznosu od gotovo trećine vrijednosti projekta, dok Dilj d.o.o. problem sufinanciranja tek treba riješiti.

Od svih poduzeća jedino je Dilj d.o.o. naišao na izvjesne izazove vezane uz pristup dobavljačima opreme zbog jako velike potražnje za elektrolizatorima, ali taj izazov je uspješno riješen. Nacionalna legislativa koja pokriva regulaciju djelatnosti svih četiriju poduzeća dobro je riješena te ishodaenje dozvola za rad ne predstavlja problem. U određenoj mjeri javljaju se izazovi pri priključenju na mrežu (što je u domeni operatera distribucijskog i prijenosnog sustava) s kojima se susreću potencijalni klijenti agregatorskih poduzeća.

Sva poduzeća sasvim opravdano smatraju da će uspješna provedba promatranih projekata omogućiti stabilniji rad elektroenergetske mreže ublažavanjem neravnoteža u elektroenergetskom sustavu, nastalih najčešće uslijed nepredvidljive proizvodnje obnovljivih izvora energije. Po mišljenju svih poduzeća, prihodi koje bi ostvarili pružanjem pomoćnih usluga (usluga fleksibilnosti) elektroenergetskom sustavu jako su nesiguran izvor prihoda. U prvom redu tu se misli na činjenicu da je jako teško za prognozirati u kojem će se smjeru tržište pomoćnih usluga razvijati i koje će cijene takvih usluga biti. Iz tog razloga teško da će za sada sami biti dostatni kako bi bili poticaj za širenje postojećih projekata i investiranje u nove na ovom području.

Poduzeća zelenu tranziciju u prvom redu smatraju izvorom prilika za razvoj poslovanja. Tako KOER d.o.o., Nano Energies Hrvatska d.o.o. i IE-ENERGY d.o.o. neupitan trend rasta stope priključenja novih obnovljivih izvora energije vide kao glavni generator potražnje za njihovim postojećim i potencijalnim novim uslugama. Dok navedena poduzeća svoju ulogu u zelenoj tranziciji prvenstveno doživljavaju kao djelovanje „prema van“, Dilj d.o.o. smatra da će zelena tranzicija njima samima pružiti priliku za povećanje energetske učinkovitosti, smanjenje energetske ovisnosti i povećati udjel korištenja alternativnih goriva i sirovina, čime će osigurati svoje mjesto u kružnom gospodarstvu.

Mišljenje da se implementacijom rješenja u poslovne procese koji podupiru zelenu tranziciju može ostvariti konkurentska prednost zastupaju svi ispitanici. Svoj stav na vlastitom primjeru najbolje objašnjava Dilj d.o.o. kao članica NEXE Grupe koja za potrebe zelene gradnje razvija niskougljične cemente,

prirodni glineni crijep te termo blokove, odnosno općenito okolišno prihvatljivije građevinske materijale.

Za brojnije pokretanje ovakvih projekata u Hrvatskoj navedeni su preduvjeti poput podizanja razine svijest svih uključenih dionika o potrebi hitne provedbe zelene tranzicije, te skraćenje vremena izdavanja dozvola za izgradnju i priključenje obnovljivih izvora energije. Potrebno je kvalitetno izraditi pravilnike i donijeti regulative kojih se svi sudionici moraju držati. Također mora postojati otvorena i učinkovita komunikacija među svim ključnim institucijama na području energetike kako bi se projekti mogli neometano razvijati. Ključno je i značajno sufinanciranje inovativnih projekata koji su od interesa cijelom društvu, te smanjenje cijene bazne opreme.

2.3. PREPORUKE ZA DALJNJA ISTRAŽIVANJA I OGRANIČENJA ISTRAŽIVAČKE METODE

U budućim istraživanjima bilo bi dobro pokušati povećati broj ispitanika, ne ustručavajući se proširiti istraživanje i na susjedne zemlje koje se nalaze u sličnoj situaciji kao i Hrvatska. Za dobivanje detaljnije slike o istraživanom problemu postavljena pitanja moglo bi se raščlaniti na nekoliko potpitanja kojima bi se stekao dublji uvid u pojavu koju istražuje, ali valja imati na umu da bi takvo istraživanje zahtijevalo i značajnu količinu vremena s obzirom na to da bi forma intervjua bila primjerenija od slanja upitnika. Istraživanje ovog tipa bilo bi dobro ponoviti u skorijoj budućnosti (za koju godinu) kako bi se vidjelo na koji se način izazovi s kojima se promatrana poduzeća mijenjaju s protekom vremena i razvojem tržišta pomoćnih usluga.

Ograničenje korištene istraživačke metode je i u malom uzorku. Naime, kako se u istraživanju promatra jedna niša unutar energetskog sektora, zbog same činjenice da se radi o niši i zbog veličine hrvatskog elektroenergetskog tržišta uzorak ispitanih poduzeća jako je malen i nije moguće uopćiti zaključke na cijeli sektor. Isto ograničenje korištene istraživačke metode proizlazi iz činjenice da uzorak nije slučajan (probabilistički) već namjeran (prigodni), što dodatno umanjuje mogućnost poopćenja rezultata istraživanja.

Jedno od ograničenja ovog istraživanja jest i nepostojanje većeg broja znanstvenih radova, knjiga i istraživanja koji se bave temom pružanja fleksibilnosti elektroenergetskom sustavu i razvojem te niše unutar sektora energetike, koji bi potvrdili ispravnost zaključaka ovog istraživanja. Razlog ovome najvjerojatnije leži u činjenici da se radi o sektorskoj niši čije je tržište u razvoju i u kojem su glavni pružatelji usluga bila velika državna poduzeća koja su svoje

kapacitete fleksibilnosti uglavnom koristili zbog tehničkog pitanja sigurnosti sustava, a ne zbog razvoja komercijalne djelatnosti temeljene na pružanju usluge balansiranja sustava. Također, zbog velikih oscilacija cijena balansiranja na unutardnevnom tržištu, a i općenito cijene električne energije, teško je sa sigurnošću projicirati zaključke o isplativosti realizacije ovakvih projekata. Konkurentsko nadmetanje na takvom tržištu jako je izazovno, te se većina podataka zadržava za sebe kao poslovna tajna.

3. ZAKLJUČAK

Kroz Europski zeleni plan pokrenut je revolucionaran prelazak na ugljično neutralno gospodarstvo, s naglaskom na održivost, energetske i resursne učinkovitost, kružno gospodarstvo te eliminaciju onečišćenja i praksi koje do njega dovode.

Općenito prevladava zaključak da je energetske sektor nužno dekarbonizirati tako da se klasični (uglavnom fosilni) izvori energije zamijene obnovljivim izvorima energije. Problemi na koje se nailazi u ostvarivanju ovog cilja kreću od same karakteristike obnovljivih izvora energije, a to u prvom redu znači nestalnost i nepredvidivost pojavnosti, primjerice vjetera ili sunčanog vremena. Zbog volatilnosti obnovljivaca može se dogoditi da energije ima premalo, ali i previše. Oni su ograničeni i geografskom lokacijom jer ih ima smisla graditi samo na najpovoljnijim položajima, što povlači i problem gubitaka u mreži zbog udaljenosti mjesta proizvodnje i potrošnje energije.

Postojeća međudržavna prijenosna mreža već je sada na gornjim granicama po opterećenju te su projekti izgradnje novih i dogradnje postojećih dalekovoda uvjet bez kojeg se ne može, te zato operatori prijenosnih sustava u Europi konstantno dorađuju svoje desetogodišnje planove razvoja mreža. U Europi će do 2030. godine biti potrebno skoro 600 milijardi eura ulaganja u energetske infrastrukturu kako bi se zadovoljio željeni cilj prihvata obnovljivih izvora energije. Zbog složenosti realizacije projekata izgradnje dalekovoda, bit će nužno ukloniti što veći broj prepreka koje danas usporavaju takve projekte.

Zeleni vodik u energetskej tranziciji ima dvojaku ulogu. Prva uloga mu je kao medij za pohranu viškova proizvedene energije iz obnovljivih izvora energije. Trenutačno je proizvodnja zelenog vodika značajno skuplja od vodika proizvedenog iz fosilnih izvora. Očekuje se da bi se taj odnos proizvodnih cijena mogao preokrenuti u bliskoj budućnosti jer se očekuje pad cijene električne energije kako bude rastao broj novih postrojenja za proizvodnju energije iz obnovljivih izvora.

Druga uloga zelenog vodika jest dekarbonizacija industrija koje je trenutačno teško dekarbonizirati, poput sektora proizvodnje čelika i cementa, gdje bi zeleni vodik zamijenio prirodni plin u proizvodnom procesu. S obzirom na početnu fazu masovnog korištenja zelenog vodika, bit će nužno visokim postotkom sufinancirati projekte kako bi potaknuli tržište i sektor zelenog vodika. Problem koji se javlja s ubrzanom izgradnjom postrojenja za elektrolizu vodika jest usporavanje dekarbonizacije energetskeg sektora jer se natječu za iste izvore obnovljive energije. Potrebno je osigurati da se izgradnja obnovljivih izvora energije odvija paralelno i u dovoljnim kapacitetima za obje namjene.

Nove nuklearne elektrane postaju sve značajniji dio energetskih sustava u nekim europskim zemljama koje su suočene s izazovom smanjenja ugljičnog otiska, a nisu uvjerene da mogu prijeći isključivo na energiju iz obnovljivih izvora na jednostavan i brz način. Jedinice koje se grade klasične su velike jedinice preko 1000 MW električne snage, a razvijaju se mali modularni nuklearni reaktori čije su prednosti prefabrikacija glavnih komponenti u tvornici čime se pojednostavljuje i ubrzava izgradnja, dulji periodi između izmjena goriva, primjerenost za male i izolirane zajednice te imaju mogućnost lakše varirati proizvodno opterećenje. Obje vrste nuklearnih reaktora pate od istih problema, a to je kašnjenje u izgradnji i jako veliki troškovi izgradnje. Unatoč tome, od njih se nije odustalo već se i dalje grade i ugovaraju nove klasične jedinice i sve se intenzivnije radi na razvoju malih modularnih reaktora.

U Hrvatskoj su također prisutni brojni projekti koji će pridonijeti ostvarenju ugljične neutralnosti Europe. U komparativnoj analizi studija slučaja predstavljeni su projekti koji bi po svojoj realizaciji mogli pružati fleksibilnost elektroenergetskoj mreži u Hrvatskoj te izazovi s kojima se takvi projekti suočavaju pri svojoj realizaciji. Izazovi s kojima se suočavaju variraju od traženja izvora sufinanciranja, otežanog pristupa dobavljačima opreme, neizvjesnosti vezane uz prihode od pružanja pomoćnih usluga, nedovoljne razine svijesti svih uključenih dionika o potrebi hitne provedbe zelene tranzicije, potrebe za skraćanje vremena izdavanja dozvola za izgradnju i priključenje obnovljivih izvora energije i drugih. Ipak, svi promatrani projekti idu naprijed dajući svoj doprinos u omogućavanju i provođenju zelene tranzicije u Hrvatskoj.

Ovakvi projekti svakako imaju smisla. Kako je navedeno u analizi, pojedini poslovni modeli već su sada isplativi bez ikakvih poticaja (agregatori), iako će u daljnjem širenju poslovanja trebati voditi računa o veličini tržišta, odnosno broju potencijalnih korisnika koji imaju mogućnost variranja proizvodnje i potrošnje. Baterijski sustavi već su sada blizu dostizanja granice isplativosti uslijed snažnog trenda pada cijena baterija te vrlo skoro možemo očekivati pojavu velikog broja takvih postrojenja u Europi, ali i Hrvatskoj. Sama tehnolo-

logija vodika još je u razvoju komponenti koje bi bile dovoljno povoljne i imale dovoljno visoku učinkovitost da postanu isplative. Ipak, proizvodnja zelenog vodika sufinancirat će se kako iz europskih sredstava tako i lokalnih u pojedinim zemljama, što će rezultirati u par narednih godina sa stvaranjem baze nove grane gospodarstva.

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THE EFFECTS OF ENERGY PRICES ON INFLATION IN THE EURO AREA / UČINCI CIJENA ENERGENATA NA INFLACIJU U EUROZONI

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The paper analyses how rising energy prices affected inflation in euro area member countries during the energy price shock in 2022. Using a Bayesian VAR model that includes energy price inflation, food price inflation, core inflation, and changes in the unemployment rate, it quantifies both the direct and indirect effects of energy price inflation on headline inflation. The results suggest that energy prices contributed significantly to headline inflation not just directly but also indirectly by affecting core and food price inflation. Furthermore, the research highlights notable variations in the direct and indirect effects of energy prices on headline inflation across euro area countries, which could affect the effectiveness of the common monetary policy. Therefore, the findings of this research are relevant within the broader context of inflation convergence and the similar transmission of energy prices across euro area countries. This convergence is crucial for the effective implementation of a single monetary policy. When inflation rates differ markedly between countries, it creates challenges for policymakers who must design decisions that could inadvertently disrupt the economic stability of countries with inflation rates that deviate substantially from the euro area average. The paper also explores potential reasons behind different transmission of energy prices to headline inflation in these countries and emphasizes the need for investment in and the promotion of renewable energy sources. By doing so, member states can reduce their dependence on volatile global energy markets and geopoliti-

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cal uncertainties, safeguarding their economies from external disruptions. This proactive approach is essential for maintaining long-term stability and securing the future prosperity of the euro area. Furthermore, the importance of a similar transmission of energy prices to inflation plays an important role in fostering cohesion and maintaining stability within the euro area. This alignment ensures stronger economic and financial integration among member countries, providing a more robust shield against future economic shocks.

Keywords: *inflation, energy price shock, inflation convergence, transmission of energy prices, euro area*

JEL classification: *E31, F45, Q43*

Rad analizira efekt rasta cijena energenata na ukupnu inflaciju u zemljama članicama eurozone tijekom iznimno snažnog šoka cijena energenata u 2022. godini. Primjenom bayesijanskog VAR modela, u koji su uključene varijable inflacije cijena energije, inflacije cijena hrane, temeljne inflacije i promjena stope nezaposlenosti, izračunati su direktni i indirektni učinci inflacije cijena energije na ukupnu inflaciju u državama članicama eurozone. Rezultati ukazuju na velik direktan doprinos cijena energenata, ali i na relativno snažan indirektan doprinos cijena energenata ukupnoj inflaciji, koji se realizira preko prelijevanja cijena energenata na temeljnu inflaciju i inflaciju cijena hrane. Rezultati također ukazuju na značajne razlike u direktnom i indirektnom doprinosu cijena energenata ukupnoj inflaciji u zemljama članicama eurozone, što može utjecati na efikasnost zajedničke monetarne politike. Stoga su rezultati ovog istraživanja relevantni u širem kontekstu konvergencije stopa inflacije i sličnog prijenosa cijena energije u zemljama europodručja. Ta je konvergencija ključna za učinkovitu provedbu jedinstvene monetarne politike. Kada se stope inflacije značajno razlikuju među zemljama, to predstavlja izazov za kreatore monetarne politike čije bi odluke mogle narušiti ekonomsku stabilnost u zemljama čije se stope inflacije znatno razlikuju od prosječne inflacije eurozone. Rad također istražuje potencijalne razloge koji stoje iza različitog prijenosa cijena energije na ukupnu inflaciju u analiziranim zemljama te naglašava potrebu za ulaganjem i promicanjem obnovljivih izvora energije. Na taj način države članice eurozone mogu smanjiti svoju ovisnost o nestabilnim globalnim energetske tržištima i geopolitičkim neizvjesnostima, štiteći svoja gospodarstva od eksternih ekonomskih šokova. Ovakav pristup ključan je za održavanje dugoročne stabilnosti i

osiguravanje budućeg prosperiteta eurozone. Naime, sličan prijenos cijena energije na ukupnu inflaciju igra važnu ulogu u osiguranju kohezije i održavanju stabilnosti unutar europodručja. Također, sličan bi prijenos doprinio snažnijoj gospodarskoj i financijskoj integraciji među zemljama članicama te smanjio ekonomske i društvene troškove potencijalnih šokova u budućnosti.

Ključne riječi: *inflacija, šok cijena energenata, konvergencija inflacije, prijenos cijena energenata, eurozona*

JEL klasifikacija: *E31, F45, Q43*

UVOD

Od sredine 2021. godine globalne cijene energenata doživjele su eksponencijalni rast, dosegnuvši tijekom 2022. godine povijesno visoke razine. Početni faktori koji su potaknuli ovaj rast uključivali su globalni ekonomski oporavak nakon pandemije bolesti COVID-19, koji je povećao potražnju za energentima, te nižu no ciljanu proizvodnju nafte od strane zemalja OPEC+. Međutim, drastičan rast cijena energenata, a posebice prirodnog plina u Europi, uslijedio je s izbijanjem rata u Ukrajini 2022. godine. Iako su cijene nafte također porasle, one su bile u okvirima uobičajenih povijesnih oscilacija, dok su cijene plina i električne energije doživjele neviđen rast (Neri i dr., 2023).

Rast cijena energenata, uključujući plin, naftu i električnu energiju, postao je ključni faktor u širenju inflacijskih pritisaka u eurozoni, ne samo putem direktnih učinaka (poskupljenje računa za energiju), već i putem indirektnih kanala, poput rasta cijena hrane i povećanja troškova proizvodnje. Direktni učinak prijenosa cijena energenata na inflaciju odnosi se na neposredno povećanje troškova potrošnje energije, što se odražava na rast cijena usluga poput struje, plina i goriva. S druge strane, indirektni učinak manifestira se kroz prijenos povećanih troškova energije na troškove proizvodnje u drugim sektorima, a potencijalno i na proces određivanja plaća i cijena (ECB 2022a, ECB 2022b), čime raste cijena proizvoda i usluga u široj ekonomiji, osobito u industrijskom i prehrambenom sektoru. Intenzitet i trajanje prijenosa cijena energenata na inflaciju razlikuje se među zemljama, što posebice može predstavljati problem za zemlje koje dijele monetarnu politiku – poput zemalja članica eurozone. Naime, različite stope inflacije među zemljama članicama stvaraju izazove za provedbu zajedničke monetarne politike Europske središnje banke (ECB). Ako se inflacija u pojedinim zemljama znatno razlikuje, jedinstven pristup ka-

matnim stopama postaje neučinkovit jer bi zemljama s višom inflacijom više odgovarala restriktivnija monetarna politika, dok bi zemlje s nižom inflacijom mogle zagovarati manje restriktivan pristup kako bi potaknule gospodarski rast. Ova dinamika može dovesti do napetosti među zemljama članicama i smanjiti efikasnost monetarne politike ECB-a.

Dodatni problemi divergencije stopa inflacije unutar monetarne unije uključuju i potencijalno širenje ekonomskih razlika među zemljama jer se zemlje s višom inflacijom suočavaju i s višim troškovima života i smanjenjem kupovne moći, dok zemlje s nižom inflacijom djeluju u stabilnijem ekonomskom okruženju. Također, viša inflacija može smanjiti konkurentnost zbog viših cijena, što negativno utječe na trgovinsku bilancu zemalja pogođenih višim inflatornim pritiscima. Povećani troškovi života u zemljama s višom inflacijom mogu dovesti i do nekih fiskalnih problema, poput većih proračunskih deficita i povećanja javnog duga. Visoka inflacija također može uzrokovati odljev kapitala i smanjenje investicija i tako dodatno povećati ekonomske nejednakosti unutar eurozone. U konačnici, smanjenje kupovne moći najviše pogađa kućanstva s nižim primanjima, što povećava društvene i ekonomske nejednakosti unutar zemalja s višom inflacijom.

Ovakve potencijalne posljedice šokova cijena energenata podcrtavaju važnost razumijevanja različitih učinaka šokova cijena energenata na inflaciju u zemljama članicama eurozone. Stoga je cilj ovog rada procijeniti i analizirati direktne i indirektne efekte rasta cijena energenata na ukupnu inflaciju u pojedinačnim zemljama članicama eurozone. Direktni i indirektni učinci procijenjeni su pomoću bayesijskog VAR modela koji uključuje inflaciju cijena energije, inflaciju cijena hrane, temeljnu inflaciju i promjenu stope nezaposlenosti po uzoru na Corsello i Tagliabraci (2023). Rezultati ukazuju na značajan direktni doprinos cijena energenata inflaciji, ali i na snažan indirektni učinak putem kanala prijenosa na temeljnu inflaciju i inflaciju hrane, pri čemu se pokazuje da se intenzitet prijenosa cijena energenata na inflaciju značajno razlikuje među zemljama. Ovi rezultati ne samo da doprinose razumijevanju procesa dinamike prijenosa cijena energenata na inflaciju, već također pružaju važne smjernice za buduće političke odluke u kontekstu energetske sigurnosti i stabilnosti unutar eurozone.

Ostatak rada organiziran je na sljedeći način. Naredno poglavlje daje pregled literature s naglaskom na promjenu fokusa s analize ekonomskih učinaka naftnih šokova na šokove cijena energenta. Podaci korišteni za analizu i metodologija opisani su u trećem dijelu rada, a rezultati istraživanja u četvrtom dijelu. U petom dijelu rada izneseni su glavni zaključci i implikacije nalaza rada za nositelje ekonomskih, a posebice energetske, politika.

PREGLED LITERATURE

Analiza korelacije između cijena energije i inflacije predstavlja ključnu temu ekonomske analize, s važnim implikacijama za poslovne cikluse i ekonomske politike. Brojna istraživanja usmjerena su na analizu utjecaja cijena nafte na ekonomiju i njezine indikatore (vidjeti primjerice Hamilton (1983), Barsky i Kilian (2004), Blanchard i Gali (2007), Kilian (2008)), dok se u posljednja dva desetljeća sve više pažnje posvećuje i širem utjecaju cijena i ostalih energenata (vidjeti Clark i Terry (2010), Kilian i Zhou (2022), Corsello i Tagliabraci (2023)).

Cijena nafte često je bila središnji fokus ranijih istraživanja zbog njezine ključne uloge u globalnom energetskom sektoru i velikog utjecaja na svjetsko tržište i ekonomske uvjete. Hamilton (1983) naglašava ne samo korelaciju, već i statističku značajnost između cijena nafte i recesija u SAD-u od 1948. do 1972. godine. Koristeći tradicionalne testove i Grangerov test uzročnosti, Hamilton (1983) zaključuje da su visoke cijene nafte značajno doprinijele izbijanju recesija, a nagli skokovi cijena nafte prethodili su većini recesija u tom razdoblju. Suprotno tomu, Barsky i Kilian (2004) ukazuju da šokovi cijena nafte nisu ni nužni ni dovoljni za objašnjenje stagflacije, naglašavajući kompleksnost interakcija između cijena nafte i ekonomske aktivnosti. Pritom Kilian (2008) ističe da jednostavne transformacije cijena nafte nisu dovoljne za prepoznavanje egzogenih šokova opskrbe naftom, te pokazuje kako kombinacija globalne potražnje i promjena u očekivanjima najviše utječe na promjene cijena.

Blanchard i Gali (2007) ističu kako su učinci šokova cijena nafte tijekom vremena smanjili, uz manji utjecaj na cijene, plaće, proizvodnju i zapošljavanje. Mogući uzroci uključuju smanjenje rigidnosti realnih plaća, veću kredibilnost monetarne politike i smanjenje udjela nafte u potrošnji. Korištenjem strukturalnog VAR modela, njihova analiza pokazuje kako su učinci šokova cijena nafte varirali tijekom vremena.

Castro i sur. (2017) istražuju prijenos cijena nafte na inflaciju u eurozoni, zaključujući da promjene u cijenama nafte snažno utječu na inflaciju energenata, dok je utjecaj na ukupnu inflaciju slabiji. Razlike među zemljama objašnjavaju se različitim indirektnim učincima, strukturama potrošnje i proizvodnje, te specifičnim oporezivanjem i regulacijom tržišta.

Utjecaj cijena energenata na ekonomiju obuhvaća širi spektar izvora energije, uključujući cijene nafte, prirodnog plina, ugljena, električne energije i obnovljivih izvora. Istraživanja u ovom području sve više prepoznaju važnost cijena drugih energenata, uzimajući u obzir njihove različite učinke na gospodarstvo, u usporedbi s naftom kao ključnim globalnim resursom. Iako su

postojeća istraživanja uglavnom bila usmjerena na naftu, nedavni geopolitički događaji i promjene u energetsom sektoru potaknuli su veći interes za analizu utjecaja cijena drugih energenata na inflaciju i ostale makroekonomske indikatore. Tako primjerice Clark i Terry (2010) analiziraju vremenske varijacije inflacijskog prijenosa cijena energenata koristeći bayesijsku metodu i zaključuju da se osjetljivost temeljne inflacije na promjene cijena energenata u SAD-u smanjuje od 1975. godine, unatoč većoj volatilnosti šokova cijena. Ovi rezultati ukazuju na smanjenje prijenosa inflacije energije na temeljnu inflaciju, što odražava promjene u ekonomiji.

S druge strane, Kilian i Zhou (2022) istražuju utjecaj šokova u cijenama energije na inflaciju, izuzevši cijene benzina. Njihovo istraživanje potvrđuje da fokusiranje isključivo na cijene benzina podcjenjuje ukupne inflatorne učinke šokova u cijeni energije, ističući njihov dominantan utjecaj na ukupnu inflaciju, dok je učinak na temeljnu inflaciju ograničen.

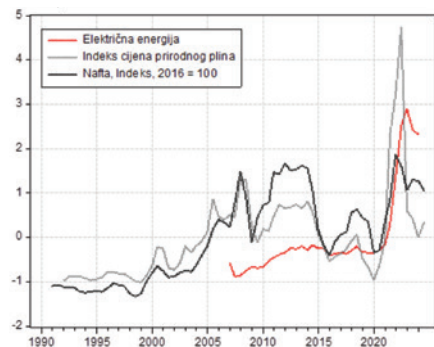
Naša analiza svih zemalja eurozone tijekom 2022. godine uvelike se oslanja na rad Corsello i Tagliabraci (2023) koji istražuju utjecaj cijena energenata na inflaciju u eurozoni, koristeći bayesijski VAR model. Njihova analiza pokazuje da je doprinos cijena energenata inflaciji u velikim europskim zemljama, osobito od sredine 2021. do rujna 2022. godine, zbog izrazitog rasta cijena energenata bio značajan.

PODACI I METODOLOGIJA

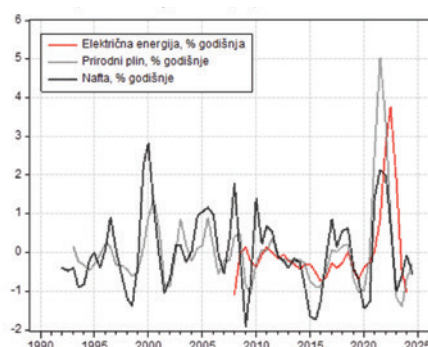
Kako je spomenuto u uvodu, od sredine 2021. godine, globalne cijene energenata doživjele su eksponencijalni rast, dosegnuvši tijekom 2022. godine povijesno visoke razine. Pritom je drastičan rast cijena energenata, a posebice prirodnog plina u Europi, uslijedio s izbijanjem rata u Ukrajini 2022. godine. Iako su cijene nafte također porasle, one su bile u okvirima uobičajenih povijesnih oscilacija, dok su cijene plina i električne energije doživjele do tada neviđen rast (vidjeti Grafikon 1.).

Grafikon 1. Cijene energenata

a) Normalizirani indeksi



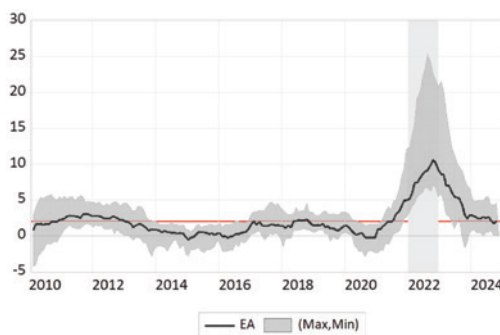
b) Godišnji rast (%)



Izvor: MMF (2024), Eurostat (2024a)

Rast cijena energenata, uključujući plin, naftu i električnu energiju, postao je ključni faktor u širenju inflacijskih pritisaka u eurozoni (vidjeti Grafikon 2.), ne samo putem direktnih učinaka (poskupljenje računa za energiju), već i putem indirektnih kanala, poput rasta cijena hrane i povećanja troškova proizvodnje.

Grafikon 2. HICP inflacija u eurozoni (% godišnje)



* Napomena: EA - Europodručje

Izvor: Eurostat (2024a)

Ovaj rad pokušava kvantificirati direktan i indirektan doprinos rasta cijena energenata inflaciji u zemljama europodručja. Analiza je provedena na temelju mjesečnih podataka o godišnjoj inflaciji mjerenoj harmoniziranim indek-

som potrošačkih cijena (HICP) energije, hrane, HICP-om bez hrane i energije (temeljni HICP) i stopama nezaposlenosti za razdoblje od siječnja 2000. do svibnja 2023. godine, za razdoblje od siječnja 2001. do svibnja 2023. godine preuzetih s Eurostata. Pri izračunu direktnih i indirektnih učinaka cijena energije na ukupnu inflaciju korišteni su udjeli HICP-a energije, hrane i temeljnog HICP-a u ukupnom HICP-u, također preuzeti s Eurostata (vidjeti Prilog 1.).

Izračun direktnih učinaka promjene cijena energije na inflaciju jest trivijalan, odnosno definiran je umnoškom godišnje stope inflacije energije i udjela energije u potrošačkoj košarici koja se koristi za izračun HICP-a.

S druge strane, procjena indirektnog učinka, odnosno učinka koji cijene energenata imaju na cijene hrane i na temeljne cijene preko rasta troškova proizvodnje i potencijalno plaća, temelji se na rezultatima VAR modela koji su prema uzoru na Corsello i Tagliabracci (2023) procijenjeni bayesijanskom metodom zbog relativno velikog broja parametara koje je potrebno procijeniti¹. Prvo je stoga za svaku zemlju potrebno procijeniti VAR model kakav je prvi predložio Sims (1980.), a koji se može zapisati na sljedeći način:

$$y_t = a_0 + A_1 y_{t-1} + A_2 y_{t-2} + \dots + A_p y_{t-p} + \varepsilon_t = a_0 + \sum_{i=1}^p A_i y_{t-i} + \varepsilon_t \quad (1)$$

gdje je $y_t = [y_{1t} \ y_{2t} \dots \ y_{Nt}]'$ N- dimenzionalni vektor koji sadrži N endogenih stacionarnih varijabli, $a_0 = [a_{10} \ a_{20} \dots \ a_{N0}]$ je N- dimenzionalni vektor konstanti, $A_1, A_2, \dots, A_p$ su NxN matrice autoregresijskih koeficijenata te je $\varepsilon_t = [\varepsilon_{1t}, \varepsilon_{2t}, \dots, \varepsilon_{Nt}]'$ vektor slučajnih procesa.

U svaki VAR model uključeno je 13 pomaka² godišnjih stopa inflacije cijene energije, inflacije cijene hrane, temeljne inflacije i promjena stopa nezaposlenosti za zemlje eurozone. Poredak varijabli usklađen je s prijedlogom Killian (2008), a koji su koristili i Corsello i Tagliabracci (2023), te implicira da na cijene energije u trenutku t mogu samo utjecati strukturni šokovi u cijenama energije, dok na temeljnu inflaciju potencijalno mogu utjecati i šokovi cijena energije i šokovi cijena hrane. Uz ovakve pretpostavke identifikacija energetskih šokova postiže se Cholesky dekompozicijom matrice varijanci-kovarijanci reziduala. Rezultirajuće funkcije impulsnog odaziva omogućavaju dekompoziciju inflacije cijena hrane i temeljne inflacije na doprinose svih šokova tijekom vremena kako je detaljno opisano u sljedećem poglavlju.

¹ Za parametre VAR modela koristimo standardne Minnesota priore koje postavljamo na $\lambda_1 = 0.1, \lambda_2 = 0.99, \lambda_3 = 1$ i $\lambda_4 = \infty$.

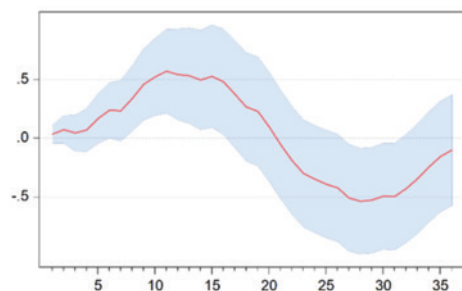
² Odabir broja vremenskih pomaka diktirala je stabilnost VAR modela za sve zemlje uključene u analizu.

REZULTATI

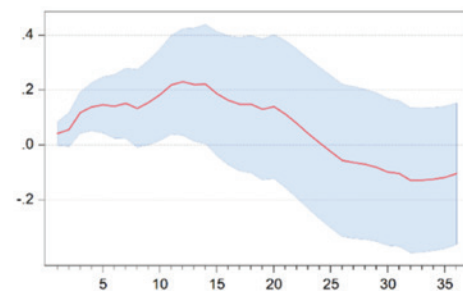
Iz procijenjenih VAR modela dolazi se do funkcija impulsnog odaziva (vidjeti Grafikon 3.) uz pomoć kojih je moguće dekomponirati inflaciju cijena hrane i temeljnu inflaciju na doprinose svih šokova tijekom vremena. Iz povijesnih dekompozicija koje daju uvid u doprinos šokova cijena energije inflaciji hrane i temeljnoj inflaciji (vidjeti Grafikon 4.) moguće je izračunati doprinos cijena energije inflaciji hrane i temeljnoj inflaciji. Stoga je ukupni indirektni učinak procijenjen kao umnožak udjela hrane i temeljne inflacije u ukupnom HICP-u i iz povijesne dekompozicije izračunatog doprinosa cijena energije inflaciji hrane i temeljnoj inflaciji (vidjeti Grafikon 3.).³

Grafikon 3. Funkcije impulsnog odaziva na šok cijena energije za Hrvatsku

a) Reakcija cijena hrane



b) Reakcija cijena bez hrane i energije



Izvor: Autor

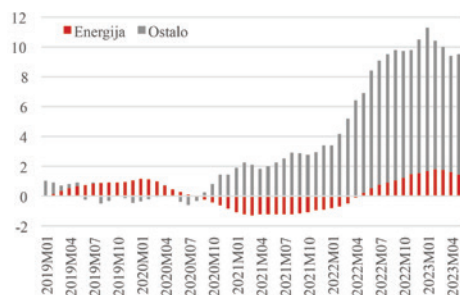
Iz Grafikona 3.a) vidljivo je da je u Hrvatskoj šok od jedne standardne devijacije u inflaciji cijena energije neznačajan do sedmog razdoblja, a zatim rezultira rastom od 0.3 postotna boda inflacije cijena hrane, dok svoj maksimum rasta od 0.61 postotna boda postiže u jedanaestom razdoblju. Iako šok postaje neznačajan tek u šesnaestom razdoblju, vrijednosti učinka kvantitativno su niske. S druge strane, Grafikon 3.b) prikazuje da šok od jedne standardne devijacije u inflaciji cijena energije rezultira rastom od 0.04 postotna boda temeljne inflacije u prvom razdoblju, a svoj maksimum od 0.26 postotna boda postiže u dvanaestom razdoblju te zatim u četrnaestom razdoblju nakon nastanka šoka

³ Prikazani (među)rezultati odnose se na Hrvatsku, a isti set rezultata dobiven je za sve zemlje eurozone. Međutim, zbog ograničenja prostora u radu ih ne prikazujemo, ali su dostupni na zahtjev.

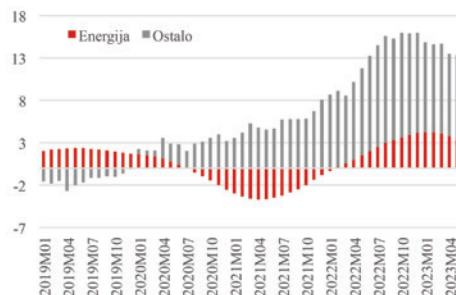
postaje neznatčan. Prema prethodno analiziranim rezultatima inflacija cijena hrane osjetljivija je od temeljne inflacije na šokove u energiji, što je konzistentno s Corsello i Tagliabraci (2023).

Grafikon 4. Doprinos šokova cijena energije inflaciji hrane i temeljnoj inflaciji

a) *Povijesna dekompozicija temeljne inflacije*



b) *Povijesna dekompozicija inflacije hrane*



Izvor: Autor

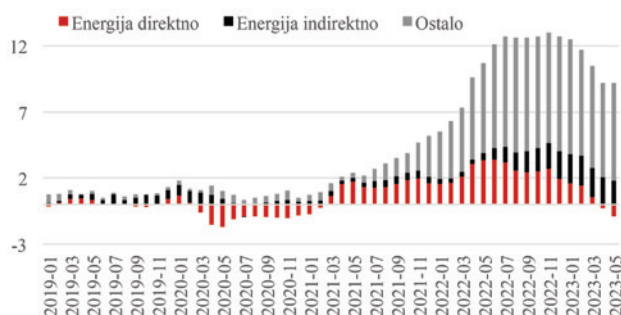
Grafikoni 4.a) i 4.b) prikazuju povijesne dekompozicije temeljnih cijena i inflacija cijena hrane za Hrvatsku u razdoblju od četiri godine (2019. – 2023.), budući da je u tom razdoblju energetska sektor doživio čak dva velika energetska šoka suprotnog djelovanja – jedan negativni 2020. godine, jedan pozitivni 2022. godine. Ova dva šoka različitog su uzroka, prvi je uzrokovan naglim smanjenjem globalne potražnje za energentima, dok je drugi dominantno uzrokovan naglim prekidom opskrbe uslijed sankcija usmjerenih Rusiji uz istovremeni rast potražnje uslijed oporavka nakon krize uzrokovane pandemijom bolesti COVID-19. Oba šoka imala su značajan utjecaj na cijene energenata, potrošačke cijene i globalnu ekonomiju općenito.

Grafikon 4.a) prikazuje povijesnu dekompoziciju temeljne inflacije Hrvatske te je vidljivo da je doprinos šoka cijena energije temeljnoj inflaciji do sedmog mjeseca 2020. godine bio pozitivan. Negativni šok cijena energije, koji se dogodio 2020. godine kao posljedica pandemije bolesti COVID-19, vršio je negativan pritisak na temeljnu inflaciju, iako se može uočiti trend oporavka u drugoj polovini 2021. godine. U 2022. godini može se primijetiti ponovni rast i pozitivan doprinos temeljnoj inflaciji, što je rezultat oporavka energetskog sektora nakon pandemije i rasta cijena energenata uslijed rata u Ukrajini. Slična dinamika vidljiva je i kod inflacije cijena hrane. Grafikon 4.b) prikazuje povijesnu dekompoziciju inflacije cijena hrane u Hrvatskoj u istom četverogo-

dišnjem razdoblju (2019. – 2023). Kroz cijelo promatrano razdoblje primjetan je veći doprinos šokova cijena energije inflaciji cijena hrane u odnosu na inflaciju temeljnih cijena. Iako se od petog mjeseca 2020. godine može primijetiti smanjenje doprinosa šokova cijena energije inflaciji cijena hrane, doprinos ostaje pozitivan sve do osmog mjeseca 2020. godine. Tada postaje negativan zbog već spomenutog negativnog energetskeg šoka uslijed pandemije bolesti COVID-19. Kao i kod temeljne inflacije, primjećuje se trend oporavka tijekom druge polovine 2021. godine, a doprinos postaje pozitivan u drugom mjesecu 2022. godine te se nastavlja i u prvih pet mjeseci 2023. godine.

Kombinirajući ove rezultate s udjelima temeljne inflacije i inflacije cijena hrane u ukupnoj inflaciji dolazi se do indirektnog doprinosa rasta cijena energenata ukupnoj inflaciji, koji je uz direktni doprinos⁴ prikazan na Grafikonu 5. Kao što je vidljivo iz Grafikona 5., u 2022. godini doprinos energije ukupnoj inflaciji raste (direktno i indirektno) te se procjenjuje da je u Hrvatskoj direktni doprinos energije ukupnoj inflaciji u prosjeku 2022. godine iznosio visokih 2.5 p. b., a indirektni 1.1 p. b.

Grafikon 5. Doprinos šokova cijena energije ukupnoj inflaciji



Izvor: Autor

S obzirom na to da se, zbog jačine i relevantnosti šoka, fokusiramo na 2022. godinu za svaku zemlju je na način prezentiran u ovom dijelu rada izračunat prosječan (postotni) direktni i indirektni doprinos cijena energije ukupnoj inflaciji tijekom te godine. Dobiveni rezultati prikazani su i analizirani u sljedećem poglavlju.

⁴ Direktni doprinos izračunat je kao umnožak godišnje stope inflacije energije i udjela energije u potrošačkoj košarici koja se koristi za izračun HICP-a.

Tablica 1. Direktni, indirektni i ukupni doprinos cijena energenata ukupnoj inflaciji

	Energija direktni učinak	Indirektni učinak energije – temeljna inflacija	Indirektni učinak energije – inflacija cijena hrane	Ukupni učinak
BE	55.7 %	17.5 %	13.9 %	87.1 %
DE	48.2 %	2.0 %	4.3 %	54.6 %
EE	54.1 %	13.5 %	10.1 %	77.7 %
IE	45.5 %	8.3 %	6.3 %	60.0 %
EL	52.9 %	18.5 %	12.5 %	83.8 %
ES	41.1 %	10.2 %	10.8 %	62.1 %
FR	41.9 %	8.2 %	8.5 %	58.5 %
HR	23.7 %	4.2 %	5.9 %	33.8 %
IT	56.5 %	11.9 %	12.9 %	81.2 %
CY	38.5 %	10.3 %	5.7 %	54.5 %
LV	45.6 %	6.6 %	14.3 %	66.5 %
LT	38.2 %	10.5 %	16.1 %	64.8 %
LU	56.0 %	6.9 %	3.9 %	66.8 %
MT	0.0 %	2.3 %	0.5 %	2.9 %
NL	70.0 %	12.6 %	6.9 %	89.4 %
AT	40.1 %	8.6 %	8.3 %	57.0 %
PT	23.6 %	10.7 %	15.1 %	49.4 %
SL	35.3 %	7.0 %	7.9 %	50.2 %
SK	23.4 %	4.5 %	5.3 %	33.2 %
FI	41.0 %	10.5 %	15.9 %	67.3 %

Izvor: Autor

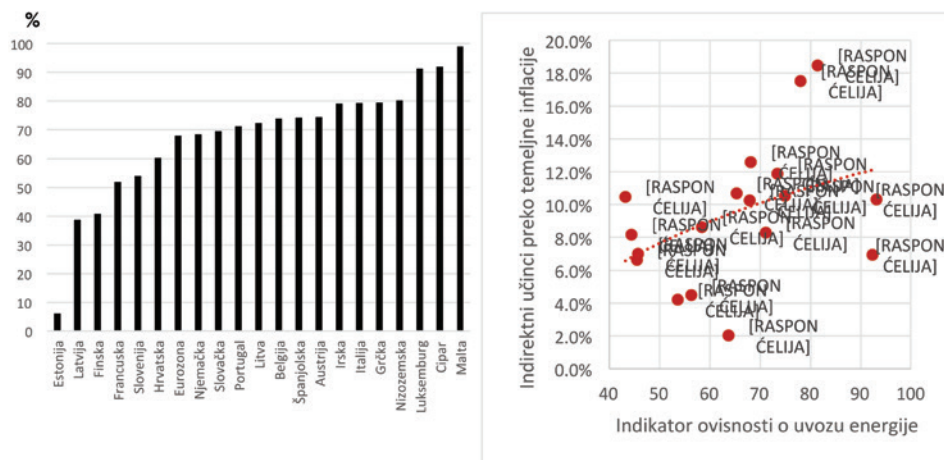
Tablica 1. prikazuje procijenjene direktne i indirektne doprinose cijena energije ukupnoj inflaciji u zemljama eurozone. Prikazane procjene sugeriraju da je energetska kriza 2022. godine znatno utjecala na stope inflacije u gotovo svim državama članicama monetarne unije. Ukupni doprinos šoka u cijenama energije na inflaciju u prosjeku 2022. godine bio je veći od 50 % u 16 od 20 zemalja članica, pri čemu je u gotovo svim zemljama članicama izuzev Portugala direktni učinak energetske šoka na inflaciju bio veći od indirektnog. Najveći direktni učinak energije na stopu inflacije, u prosjeku 2022. godine, zabilježen je u Nizozemskoj i iznosio je otprilike 70 %, a najniži u Malti u kojoj nije bilo direktnog učinka energije na inflaciju (0 %), što je posljedica mjere donesene

od strane malteške vlade u kojoj je vlada naložila Enemalti, državnom energetsom dobavljaču u vlasništvu države (67 %), da zamrzne cijene na razini iz 2014. godine. Malta je u prosjeku 2022. godine također zabilježila i najniži indirektni učinak od samo 2.9 %, dok je najviši indirektni učinak ostvaren u Belgiji (31.4 %). Najveći ukupni učinak zabilježila je Nizozemska (89.4 %), dok je Malta imala najniži (2.9 %). Hrvatska je druga zemlja članica nakon Malte sa samo 33.8 % ukupnog učinka energije na inflaciju.

Razlike u direktnim, a posebice indirektnim, učincima šokova cijena energije na inflaciju između ostalog proizlaze iz različitih struktura energetskih sektora zemalja članica, koje određuju razni čimbenici. Jedan od mogućih čimbenika jest strategija nabave energenata, koja uvelike ovisi o geografskom položaju zemalja. U kontekstu energetskih šokova i kriza, bitna je karakteristika je li određena država neto izvoznik ili neto uvoznik energije. Kada su zemlje neto uvoznici energije, više cijene energije obično pogoršavaju njihove uvjete trgovine. Visoke cijene energije prenose bogatstvo iz zemalja koje uvoze naftu prema zemljama koje je izvoze, a taj učinak bogatstva ima negativan utjecaj na potrošnju u zemljama koje uvoze energiju putem multiplikativnih učinaka (ECB, 2022a). Na Grafikonu 6.a) prikazan je indikator ovisnosti o uvozu energije u 2022. godini, koji pokazuje udio ukupnih energetskih potreba zemlje koje se zadovoljavaju uvozom iz drugih zemalja. Stopa prikazuje udio energije koju gospodarstvo mora uvoziti, a računa se kao neto uvoz energije podijeljen s bruto dostupnom energijom, izraženom kao postotak. Kako je moguće vidjeti na Grafikonu 6.b) ovaj indikator pozitivno je koreliran s indirektnim doprinosom cijena energije ukupnoj inflaciji. Stoga trenutačni geopolitički događaji ističu važnost kontrole i smanjenja ovisnosti o uvozu energenata u članicama eurozone. Ovisnost o uvozu energije izlaže europsku ekonomiju volatilnim cijenama na svjetskom tržištu i riziku smanjenja opskrbe. Rizici se povećavaju s ovisnošću o pojedinim zemljama, što može biti određeno infrastrukturom opskrbe. Ovakvi rezultati podcrtavaju važnost jačanja domaće proizvodnje energije, uključujući povećanje proizvodnje energije iz obnovljivih izvora, energetske učinkovitost i osiguravanje nedostajuće infrastrukture.

Grafikon 6. Indikator ovisnosti o uvozu energije i indirektni učinci cijena energije

- a) Indikator ovisnosti o uvozu energije b) Indikator ovisnosti vs indirektni učinci preko temeljne inflacije*



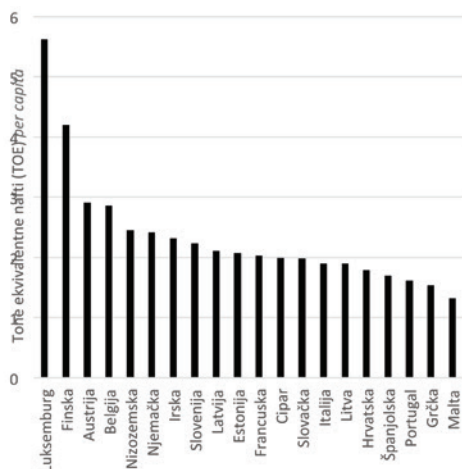
* Malta je isključena zbog ekstremnog učinka implementiranih politika tijekom energetskeg šoka. Estonija je isključena zbog jedinstvenog pristupa različitim energentima.

Izvor: Eurostat (2024c), autor

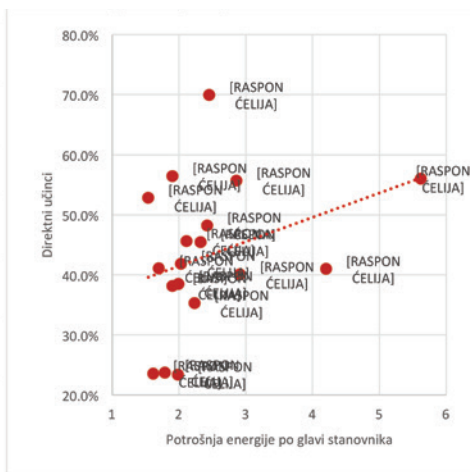
Razlikama u direktnim učincima zasigurno doprinose razlike u potrošnji energije *per capita*, a koje ne ovise samo o geografskim i klimatskim obilježjima, već i o razini razvijenosti pojedinih zemalja. Iz Grafikona 7. a) vidljivo je da je, iako su neke od zemalja imale vrlo visoku ovisnost o uvozu energije, potrošnja energije *per capita* bila na niskim razinama te je i to jedan od mogućih razloga zbog kojih direktni (a potencijalno i indirektni) učinak energije na ukupnu inflaciju nije bio visok kao u državama članicama koje imaju vrlo visoke razine energetske potrošnje. Najnižu potrošnju energije 2022. godine imala je Malta, a najvišu Luksemburg. Grafikon 7. b) sugerira da između potrošnje energije *per capita* i direktnog doprinosa cijena energije ukupnoj inflaciji postoji pozitivna veza. To ukazuje na važnost konvergencije dohodaka u monetarnoj uniji koja može doprinijeti konvergenciji potrošnje energije po glavi stanovnika, a samim time doprinijeti i konvergenciji stopa inflacije u zemljama monetarne unije.

Grafikon 7. *Potrošnja energije po glavi stanovnika i direktni učinci cijena energije*

a) *Indikator ovisnosti o uvozu energije*



b) *Potrošnja p/c vs direktni učinci na ukupnu inflaciju**



* Malta je isključena zbog ekstremnog učinka implementiranih politika tijekom energetskeg šoka. Estonija je isključena zbog jedinstvenog pristupa različitim energentima.

Izvor: Eurostat (2024d), autor

ZAKLJUČAK

Europska ekonomija u posljednje četiri godine bila je suočena s dva velika šoka cijena energenata (2020. i 2022.), koji su imali suprotna djelovanja. Nakon negativnog šoka u 2020. godini, uslijed pada potražnje uzrokovanog pandemijom bolesti COVID-19, cijene energenata su se smanjile. Međutim, 2022. godine, početak geopolitičkih nestabilnosti doveo je do drastičnog porasta cijena energenata, koje su dosegnule dotad nezabilježene razine. Ova situacija naglasila je ranjivost zemalja članica eurozone na fluktuacije cijena energenata na svjetskom tržištu, kao i njihovu ovisnost o političkim odnosima s trećim zemljama. Istodobno, postala je očita važnost diverzifikacije opskrbe energijom i poticanja proizvodnje energije iz obnovljivih izvora. Visoka inflacija koja je pogodila zemlje eurozone, a kao što je prikazano u ovom radu, u velikoj mjeri je bila povezana s rastom cijena energije.

Pritom se prijenos cijena energenata na inflaciju odvijao i putem direktnih (veći troškovi za plin, struju, gorivo) i putem indirektnih (povećanje troškova proizvodnje) kanala, a u ovom su radu procijenjeni doprinosi cijena energenata inflaciji zemalja članica eurozone u 2022. godini putem obaju kanala. Rezultati istraživanja pokazuju da su učinci šokova cijena energenata na ukupnu inflaciju bili značajni, ali i da su jako varirali među zemljama eurozone. Ove varijacije proizlaze iz različitosti energetske strukture, ovisnosti o uvozu energenata, različitih razina dohotka i sektorske strukture koje utječu na potrošnju energije, kao i iz različitih odgovora ekonomskih politika na šokove cijena energenata u 2022. godini.

Analiza sugerira da su šokovi u cijenama energije indirektno najviše utjecali na ukupnu inflaciju u zemljama s visokom ovisnošću o uvozu energije, posebno onima koje su bile vrlo ovisne o ruskom plinu, s iznimkom Malte⁵. Daljnje razlike u izravnim učincima rezultat su različitih udjela energije u ukupnoj potrošnji, što utječe na težinske udjele energije u ukupnom HICP-u među zemljama, kao i različitih mjera potpore kućanstvima i malim i srednjim poduzećima koje su vlade donijele.

Rezultati ovog istraživanja važni su za razumijevanje procesa konvergencije inflacije i njegove ovisnosti o sličnom prijenosu cijena energenata unutar eurozone, što je nužan preduvjet za uspješno vođenje zajedničke monetarne politike. Velike razlike u stopama inflacije uslijed različitog prijenosa šokova cijena energenata mogu otežati donošenje ekonomskih politika (posebice monetarne) jer odluke koje donose nositelji ekonomske politike mogu negativno utjecati na stabilnost zemalja čija stopa inflacije znatno odskake od prosjeka eurozone. Na kraju, ujednačen prijenos cijena energenata na inflaciju ključan je za jačanje kohezije i stabilnosti unutar eurozone, čime se osigurava bolja zaštita ekonomske i financijske integracije među zemljama članicama.

S obzirom na sve veći značaj energetske opskrbe u suvremenom društvu, stabilnost i pouzdanost izvora energije postaju presudni za produktivnost, gospodarski rast i ekonomsku stabilnost. Zemlje izvoznice energenata imaju ključan utjecaj na globalne trgovinske tokove i geopolitičke odnose, a cijene energenata mogu snažno utjecati na valutne tečajeve, trgovinske sporazume i političke odluke. Ovisnost o uvozu energenata, poput nafte i plina, čini drža-

⁵ Iako je Malta gotovo u potpunosti ovisna o uvozu energije, šokovi cijena energije nisu izravno povećali inflaciju u prosjeku 2022. godine. Ovaj rezultat posljedica je mjera koje je malteška vlada poduzela, naloživši svom državnom energetske dobavljaču, Enemalti, da zamrzne cijene na razini iz 2014. godine, uz nadoknadu gubitaka nastalih zbog viših troškova uvoza energije. (Bruegel, 2023).

ve i regije osjetljivijima na geopolitičke događaje. Stoga diverzifikacija izvora energije postaje strateški prioritet za smanjenje tih rizika i povećanje ekonomske stabilnosti unutar eurozone. Konačno, brža konvergencija dohodaka putem smanjenja razlika u udjelu potrošnje energije u ukupnoj potrošnji, uz bolju koordinaciju ekonomskih politika u slučaju snažnih šokova cijena energenata, značajno bi doprinijela sličnijoj transmisiji energetske šokove na inflaciju među zemljama članicama eurozone, čime bi se osigurao efikasniji okvir za vođenje zajedničke monetarne politike.

PRILOG 1.

Tablica P1. Podaci i izvori podataka

Varijabla	Podaci	Vremensko razdoblje	Izvor
Cijene bez hrane i energije (temeljna inflacija)	Overall index excluding energy, food, alcohol and tobacco	siječanj 2000. do svibnja 2023.	Eurostat (2023a) [TOT_X_NRG_FOOD]
Cijene hrane	Food including alcohol and tobacco	siječanj 2000. do svibnja 2023.	Eurostat (2023a) [FOOD]
Cijene energije	Energy	siječanj 2000. do svibnja 2023.	Eurostat (2023a) [NRG]
Stopa nezaposlenosti	Unemployment rate (%) - monthly data - Percentage of population in the labour force - Seasonally adjusted data, not calendar adjusted data	siječanj 2000. do svibnja 2023.	Eurostat (2023b)

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BUILDING A RESILIENT FUTURE THROUGH ENVIRONMENTAL PROTECTION: HOW EUROPEAN GREEN INVESTMENTS DRIVE SOCIO-ECONOMIC SAFEGUARDS

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This study examines the socio-economic implications of investments, transfers, and expenditures in environmental protection, specifically analyzing their impact on the quality of life in selected European countries. The study focuses on the key indicators, namely GDP per capita and Green GDP, with the latter offering a more sustainable and comprehensive measure of economic performance. The research posits that while GDPpc growth is a desirable outcome, GDP growth that neglects environmental considerations is an undesirable result. In order to explore this relationship, the study employs panel cointegration modeling across 15 European countries in the period from 2014 to 2021. The analysis yields two key findings: (i) a significant positive nexus between environmental investments, transfers, expenditures, and GDPpc, highlighting the potential of environmental spending to improve economic well-being; (ii) an inverse relationship between these environmental expenditures and the so-called Green GDP gap, emphasizing the importance of “green spending” in advancing sustainable economic growth. These findings suggest that socio-economic prosperity and green economy goals can coexist, with the European continent making notable strides in balancing economic growth with environmental sustainability. Moreover, this balance contributes to addressing environmental injustices and promoting social equity, illus-

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trating the broader positive effects of green investments on both economic and social outcomes.

Keywords: *European countries, green economic growth, green investments, environmental protection, panel cointegration analysis*

JEL classification: *A13, D4, D5, E1, Q5*

INTRODUCTION

This study examines the interconnections between social equality, green economic growth, and investments in environmental protection in Europe. It highlights how environmental degradation exacerbates social inequalities, disproportionately affecting marginalized communities. Conversely, investments in environmental protection can act as a critical driver for addressing these disparities, creating green jobs, ensuring access to clean resources, and enhancing societal resilience. Recognizing this nexus accentuates the need for integrated approaches to development that balance economic growth, environmental sustainability, and social fairness. By fostering synergies between these dimensions, policymakers, businesses, and communities can pave the way for a more sustainable and greener future. A green economy framework prioritizes resource efficiency, reduced carbon emissions, and the promotion of renewable energy, offering a pathway toward sustainable development and green economic growth. Within this framework, sustainability aligns ecological preservation with human well-being, highlighting the fundamental link between a healthy environment and improved quality of life for current and future generations. Moreover, addressing environmental challenges caused by global production and consumption processes necessitates acknowledging the role of environmental justice in mitigating inequalities and promoting social fairness. Hence, a relatively new concept of Green GDP supports the idea of aligning economic development with improvements in physical, human, and natural capital.

The study explores the socio-economic implications of investments, transfers, and expenditures in environmental protection, focusing on their impact on the quality of life in selected European countries. Key indicators include GDP per capita (GDPpc) and Green GDP, with the latter representing a more sustainable approach to measuring economic performance. The study adopts the view that GDPpc growth is a desirable outcome, while GDP growth without considering green aspects constitutes an undesirable output. The research approach utilizes panel cointegration modeling across 15 European countries following the

period 2014–2021, depending on the data availability. The analysis reveals two critical findings: first, a significant positive relationship between investments/transfers/expenditures in environmental protection and GDPpc, demonstrating the potential for environmental spending to enhance economic well-being; second, an inverse relationship between environmental investments/transfers/expenditures and the so-called green gap variable, affirming the role of “green spending” in advancing green economic aspirations. These findings illustrate that socio-economic prosperity can coexist with green economy aspirations, reflecting the positive implications of European countries’ progress in balancing economic growth with environmental sustainability. Furthermore, this balance contributes to addressing environmental injustices and fostering social equity.

In conclusion, the study affirms that investments in environmental protection are integral to achieving sustainable economic growth while promoting societal well-being. The European “model” demonstrates the potential to harmonize economic, ecological, and social dimensions, offering valuable insights for global efforts to combat environmental injustices and build resilient, inclusive societies.

THEORETICAL BACKGROUND

In an era where the relentless pursuit of ever-higher growth rates remains unparalleled, the notion of unchecked growth faces increasing scrutiny (Stjepanović, Tomić, and Škare, 2019). Economic growth is typically assessed through changes in GDP, a key indicator measuring the flows of output and income within an economy. While GDP effectively captures the patterns and dynamics of economic expansion, this reductionist approach, prevalent in mainstream economic theory and policy, often overlooks the adverse consequences of such growth on socio-economic systems. Economic growth undeniably enhances the quality of life up to a certain threshold. However, beyond this point, it frequently has detrimental effects, a phenomenon known as the “threshold effect.” When this critical juncture is exceeded, the negative externalities of growth, such as escalating income inequality, erosion of leisure time, and the depletion of natural resources, can outweigh its benefits, ultimately diminishing overall well-being. This raises a pivotal question: Can fair and sustainable development coexist with the prevailing paradigms of economic growth? Besides the ongoing discourse on reconciling well-being with economic progress, one concept emerges as particularly compelling: the pursuit of green growth. This framework seeks to integrate environmental sustainability with economic

advancement, offering a pathway to balance prosperity and ecological preservation. By emphasizing resource efficiency, inclusivity, and resilience, green growth presents a holistic approach to addressing the complex interplay between growth and sustainability in modern economies.

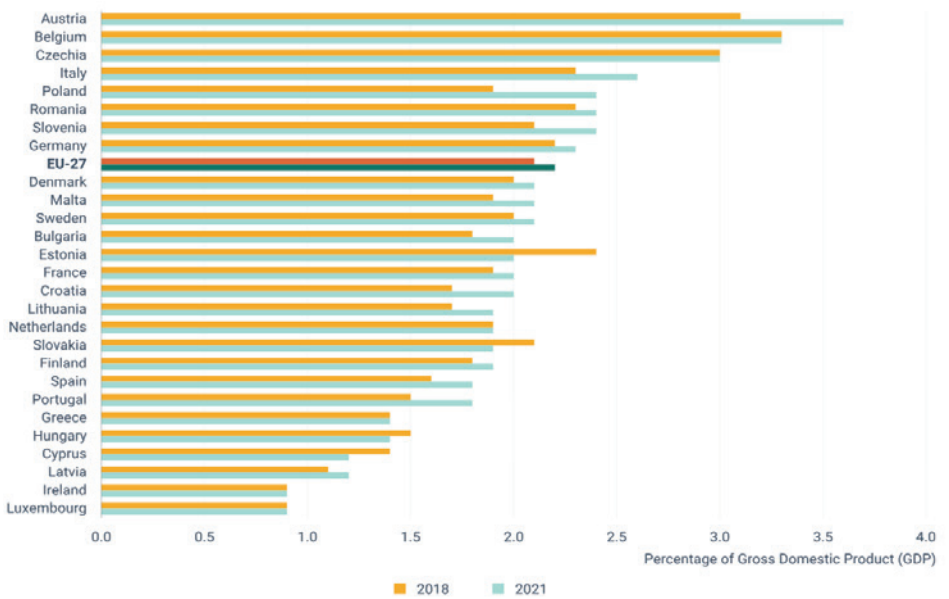
As the European Union endeavors to harmonize traditional methods of environmental conservation across its Member States, questions have emerged regarding its capacity to fully meet this ambitious objective. The ability of Member States to comply with EU environmental protection regulations varies significantly, ranging from advanced levels of implementation to rudimentary stages of development. These disparities are particularly pronounced in the context of recent institutional changes, wherein administrative responsibilities and regulatory enforcement have increasingly shifted from individual nations to centralized EU institutions (Alibašić and Atkinson, 2023). In response to these challenges, Member States have developed mitigation strategies to address the multifaceted issue of climate change, as articulated in their Intended Nationally Determined Contributions (INDCs) under the framework of the Paris Agreement. Concurrently, the EU and national governments have delineated long-term targets for 2050, aligning these goals with the broader objectives of the European Green Deal and EU climate priorities. This paradigm shift represents a deliberate effort to integrate economic objectives with environmental imperatives, fostering a holistic approach to sustainable development. By prioritizing resource efficiency, carbon neutrality, and socio-economic equity, these initiatives aim to establish a more resilient and inclusive foundation for societal progress, positioning the EU as a global leader in climate action and sustainability (Eurostat, 2024).

As the significance of environmentally sustainable practices becomes increasingly evident, a parallel rise in public awareness and activism surrounding environmental issues is likely to follow. This heightened awareness may prompt citizens to demand greater transparency and accountability from governments and corporations regarding their environmental footprints. Such societal pressures can drive the implementation of more ambitious climate policies and the development of robust sustainable development initiatives, fostering a collective commitment to environmental leadership. The integration of sustainable practices offers substantial benefits for public health and overall quality of life. For instance, reductions in air and water pollution, alongside improved access to green spaces, contribute to the creation of healthier, more livable urban and rural environments. These improvements not only enhance community well-being, but also lower healthcare expenditures by mitigating illnesses linked to environmental pollutants. Moreover, increased investments in environmental protection catalyze advancements in technology, policy frameworks, and sus-

tainable practices aimed at curbing environmental degradation. Such financial commitments accelerate the innovation and deployment of cleaner technologies, renewable energy solutions, and resource-efficient production methods. These developments not only address environmental challenges, but also stimulate economic growth by fostering industries centered around sustainability and green innovation, thereby promoting a circular and resilient economy.

Between 1995 and 2022, European Union expenditure on environmental protection exhibited remarkable stability, consistently ranging between 0.7% and 0.9% of GDP. Similarly, its share within total government expenditure remained relatively constant, fluctuating between 1.4% and 1.7%. In the period from 2021 to 2022, total EU government expenditure on environmental protection increased significantly, rising by €11 billion, from €119 billion to €130 billion. Despite this absolute growth, the expenditure-to-GDP ratio (0.8%) and its proportion within total public spending (1.6%) remained unchanged (Eurostat, 2024).

Figure 1: Expenditure on environmental protection by EU members, 2018 and 2021, (% of GDP)

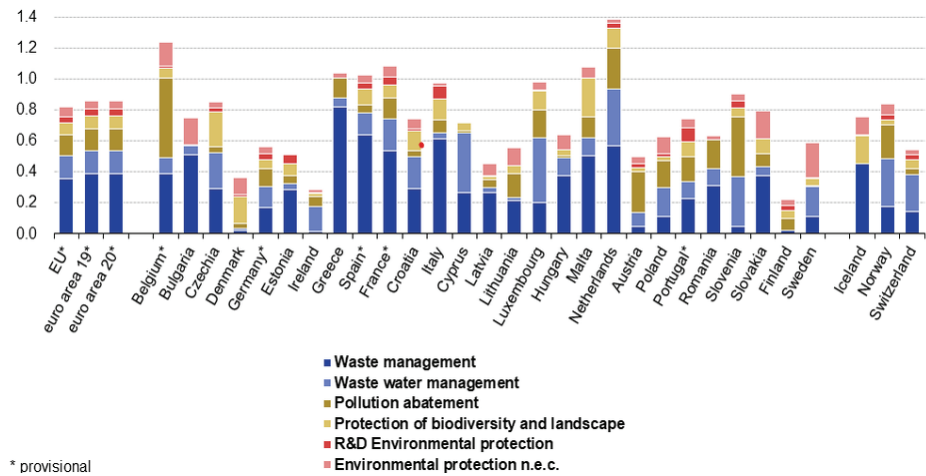


Source: European Environment Agency, 2023

From 2018 to 2023, climate and environment related expenditure within the EU expanded from €280 billion to €357 billion, representing a real-term in-

crease of 7% after adjusting for inflation (European Environment Agency, 2024). Within this timeframe, the environmental protection expenditure of general governments and non-profit institutions grew by 12%, while household contributions to environmental protection expenditures declined by 11%. A substantial portion of this spending was allocated to waste management and wastewater treatment, emphasizing the focus on essential infrastructure and pollution mitigation. The ratio of total environmental protection expenditure to GDP has remained relatively stable, hovering around 2% since 2018. However, this ratio slightly decreased from 2.2% in 2022 to 2.1% in 2023. Investments specifically designated for environmental protection constituted a modest share of the overall expenditure, accounting for 19% in 2023. In real terms (2010 prices), such investments increased from €47 billion in 2018 to €51 billion in 2022. These ratios, however, displayed significant variation among the Member States (Figure 1). For example, Austria, Belgium, and Czechia allocated over 3% of GDP to environmental investments, while Ireland and Luxembourg invested less than 1%. Notably, 17 of the 27 EU Member States reported an increase in this share during the period, with the largest gains observed in Poland and Austria (0.5 percentage points). Conversely, four countries experienced declines, with Estonia showing the largest decrease (0.4 percentage points), while six states reported no significant change. This diverse fiscal landscape underscores the heterogeneity of environmental investment trajectories within the EU (Eurostat, 2023).

Figure 2: General government expenditure on environmental protection, 2022 (% of GDP)



Source: Eurostat 2024

In 2022, the Netherlands allocated the highest proportion of GDP to environmental protection among the EU Member States, dedicating 1.4% of GDP to this domain. It was followed by Belgium, France and Malta. A detailed breakdown reveals that in the Netherlands, 0.6% of GDP was directed toward waste management and 0.4% toward wastewater management. Belgium allocated 0.4% of GDP to waste management and 0.5% to pollution abatement, driven largely by tax-subsidy schemes supporting renewable energy (Figure 2). Conversely, countries with the lowest ratios of GDP devoted to environmental protection included Finland, Ireland, and Denmark. When examining specific functions of environmental protection, Greece recorded the highest ratio of GDP devoted to waste management (0.8%), followed by Spain, Italy, and the Netherlands. In terms of wastewater management, Luxembourg, Cyprus, and the Netherlands led with 0.4% of GDP. Belgium stood out with the highest ratio of GDP dedicated to pollution abatement (0.5%), primarily due to its investment in renewable energy initiatives. Regarding the protection of biodiversity and landscapes, EU countries allocated between 0.1% and 0.3% of GDP in 2022, with Malta reporting the highest expenditure at 0.3%. Expenditure on research and development (R&D) related to environmental protection was notably low across all EU Member States, amounting to 0.1% of GDP or less in 2022. This underinvestment in R&D highlights a potential gap in fostering innovation critical for advancing long-term environmental goals (Eurostat, 2024).

EMPIRICAL BACKGROUND

Next, there is a review of the most recent studies related to the research topic, highlighting the key findings and trends that contribute to a deeper understanding of the subject matter. For deeper insight into other related studies, read Tomić (2024). Georgieva (2024) examined the relationships among economic development, environmental investments, and greenhouse gas emissions in the European Union from 2008 to 2022. Through correlation and regression analyses, the study evaluated the influence of environmental protection expenditure and gross domestic product on greenhouse gas emissions. Their findings highlighted a consistent upward trajectory in environmental protection expenditure, particularly in recent years, underscoring the European Union's intensified focus on sustainable development. Hence, greenhouse gas emissions exhibited an overall decline, with the most pronounced reduction occurring between 2019 and 2020, likely attributable to the effects of the COVID-19 pandemic. Correlation analysis revealed a significant inverse association be-

tween environmental investments and emissions, affirming the effectiveness of “green” expenditure in mitigating carbon footprints. Niu (2024) used a panel Tobit model to examine the relationship between government expenditure on environmental protection and national Environmental, Social, and Governance (ESG) performance. The analysis identified a statistically significant positive association, demonstrating that increased government investment in environmental protection is correlated with enhanced ESG performance. The study also revealed that resource allocation toward environmental protection not only improves ecological and social outcomes, but also contributes to advancements in governance standards.

Čábelková et al. (2023) examined the relationships between public preferences for environmental protection, economic growth, and individual freedoms across eleven post-Soviet countries – with analyses introducing correlations, principal component analysis, and ordinal regression methodologies. Findings indicated that preferences for most personal freedoms significantly influence preferences for both environmental protection and economic growth. Specifically, higher preferences for civil rights, democratic principles, gender equality, reduced income inequality, and limiting the military’s role in politics are associated with stronger support for environmental protection and economic growth. Shayegh et al. (2023) explored alternative pathways for transitioning the global economy from a fossil-fuel-dominated brown sector to a low-emission green sector. Their findings revealed that the primary challenge of the green transition centers on capital formation, accumulation, and reallocation, supported by comprehensive R&D investment aimed at enhancing the green sector’s productivity. Thus, their results demonstrated that each transition pathway employs distinct mechanisms to achieve its objectives. Using provincial panel data from China spanning from 2005 to 2021, Wang and Zhou (2023) employed fixed-effect and mediating-effect models to analyze the impact of government environmental investment on green development. Their findings revealed that government environmental investment positively influences green development, and although this effect has diminished over time, the investment indirectly fosters green development by promoting green patent applications and enhancing economic agglomeration, and they also observed that the effectiveness of government environmental investment varies by region and time period. Zhang (2023) employed panel regression analysis and a two-step generalized method of moments approach to address endogeneity, examining the relationships among green finance, financial technology, and high-quality economic development in three South Asian economies from 2000 to 2018. Their findings revealed that India, Bangladesh, and Pakistan

have implemented diverse green financing initiatives, which significantly reduced commercial CO₂ emissions over the study period. These results favored green financing in advancing environmental protection and supported the concept of green economic recovery.

Arjomandi et al. (2022) utilized the Autoregressive Distributed Lag (ARDL) model to analyze the short-term and long-term effects of environmental policy stringency and environmental expenditures on pollution-adjusted GDP and productivity growth in various OECD countries. Despite notable variations in policies and outcomes among nations, the study demonstrates that, in the short term, government investments in environmental protection significantly stimulate national economic growth. Feng et al. (2022) employed data envelopment analysis and generalized method of moments to examine the relationship between government expenditure and green economic performance, utilizing panel data from 2008 to 2018 across selected BRI countries. Their findings indicated that fluctuations in the green economic performance index within BRI nations are primarily attributed to insufficiently robust government policies. Additionally, the econometric analysis revealed that government expenditure has a significant positive impact on green economic performance, suggesting that public investment in human capital and renewable energy fosters a more productive green economy by enhancing labor efficiency and advancing technical development practices, with effects varying across different countries. Yang, Gao, and Li (2022) conducted a study examining the relationship between economic development and environmental well-being, with a focus on the decoupling dynamics of economic growth and environmental impacts across 30 Chinese regions. The analysis revealed a positive trend, indicating an improving relationship between economic activities and environmental conservation. Their findings suggested that efforts towards economic growth and environmental protection have produced a mutually beneficial outcome, facilitating a “win-win” scenario.

Gan et al. (2021) employed empirical analysis to investigate the relationships between regional economic development, green corporate image, and enterprise environmental protection investment, utilizing data from A-share manufacturing firms listed in China between 2007 and 2015. Their research indicated that a strong green corporate image positively influences environmental protection investment by enterprises, with the level of regional economic development serving as a partial mediator in this relationship. Finally, their results further accentuated that a robust green image conveys positive signals to stakeholders, enhancing their loyalty and satisfaction with the enterprise’s products and services. Batini et al. (2021) calculated the economic

multipliers of investments in clean energy and biodiversity conservation to guide stimulus measures for a sustainable post-COVID-19 recovery. Utilizing a newly compiled international dataset, the analysis revealed that each dollar allocated to carbon-neutral or carbon-sink initiatives yields over a dollar's worth of economic benefits (these multipliers were estimated to be 2 to 7 times higher than those of non-eco-friendly expenditures, varying by sector, technology, and time frame). Gallo and Ndiaye (2021) analyzed the data from 1995 to 2017 across 28 OECD countries in order to investigate the dynamics of strategic interactions in environmental expenditures. Using a spatial Durbin model, their study revealed a significant positive spatial dependence in environmental spending among OECD countries, suggesting that the environmental policies of neighboring nations exert an influence on each other's decisions regarding expenditure in this domain. Vavoura and Vavouras (2022) argued that the green growth strategy represents a modified version of the conventional economic growth model, incorporating specific environmental considerations within the European Union. The authors demonstrated that, while per capita income continues to rise, expenditures on environmental protection are increasing at a significantly slower rate. Notably, their analysis identified a distinct decline in investments directed towards environmental protection.

METHODOLOGY

DATA AND MODELING

This study utilizes annual data on gross domestic product per capita, environmental investments, transfers and expenditures spanning the period 2014-2021 (depending on data availability of each variable) and sourced from Eurostat (Eurostat, 2024), covering a representative sample of 15 European countries (Belgium, Bulgaria, Estonia, Greece, Ireland, Spain, France, Croatia, Italy, Lithuania, Austria, Poland, Portugal, Romania and Slovenia), due to data unavailability on the environmentally related variables from other European countries. Green GDP indicator was retrieved from the Stjepanović, Tomić and Škare (2022) database, which provides an alternative framework for evaluating sustainability and green growth (Stjepanović, Tomić and Škare, 2017). All three environmental variables are showing increasing patterns with almost similar movements across the countries and over time. Such similarities in the movements between the variables indirectly point us to the question of sample homogeneity. Thus, the presumption of homogeneity among countries suggests

that the panel data approach should be an appropriate method for answering this research question.

The primary objective of this study is to empirically assess the impact of various environmental investments on the green growth perspective, utilizing a panel cointegration approach. To achieve this, the following equation is estimated, allowing for a comprehensive analysis of the relationship between these investments and sustainable economic growth:

$$\ln GDP_{pc\ it} = \alpha_{0i} + \alpha_{1i} \ln EPE_{it} + \alpha_{2i} \ln EPI_{it} + \alpha_{3i} \ln EPT_{it} + \mu_{it} \quad i = 1, 2, \dots, N; t = 1, 2, \dots, T \quad (1)$$

$$\ln GAP_{it} = \beta_{0i} + \beta_{1i} \ln EPE_{it} + \beta_{2i} \ln EPI_{it} + \beta_{3i} \ln EPT_{it} + \mu_{it} \quad i = 1, 2, \dots, N; t = 1, 2, \dots, T \quad (2)$$

For analytical precision, all datasets were transformed into their logarithmic form. The variable $\ln GDP_{pc}$ displays the logarithm of the ratio of real GDP to average population of a specific year in euros, $\ln GAP$ represents the logarithm of the deviation of Green GDP from the standard GDP measure in current U.S. dollars (the variable is in dollars due to a particularity of the calculation method), $\ln EPE$ represents the logarithm of national expenditure on environmental protection by institutional sector in euros, $\ln EPI$ stands for the logarithm of environmental protection investments of the total economy in euros, and $\ln EPT$ signifies the logarithm of environmental protection transfers categorized by activity and institutional sector in euros.

APPLIED METHOD; PANEL COINTEGRATION ANALYSIS

In order to analyze the effects of environmental investments, transfers, and expenditures on GDP_{pc} (sample 2014–2021) and the green gap variable (2014–2019), a linear panel data cointegration analysis is applied. The integration order of the time series is determined using panel unit root tests. If the series are found to be integrated of order 1 (i.e., non-stationary), the analysis proceeds with panel cointegration testing. For determining the order of integration, several tests are employed: the LLC test (Levin, Lin and Chu, 2002), the Breitung test (Breitung, 2000), the IPS test (Im, Pesaran and Shin, 2003), and Fisher-type tests using ADF and PP statistics (Maddala and Wu, 1999; Choi, 2001).

Panel cointegration is assessed using the methods proposed by Pedroni (1999, 2004), Kao (1999), and Maddala and Wu (1999). Pedroni and Kao ex-

tend the two-step Engle-Granger (1987) framework to panel data. Pedroni introduces multiple tests for cointegration that account for heterogeneous intercepts and trend coefficients across cross-sections, offering two alternative hypotheses: the homogeneous alternative (within-dimension or panel statistics) and the heterogeneous alternative (between-dimension or group statistics). The Kao test similarly builds on Pedroni's framework, but assumes cross-section-specific intercepts and homogeneous first-stage regressor coefficients.

The long-run relationships are estimated using pooled Panel Fully Modified Least Squares (FMOLS), pooled Panel Dynamic Least Squares (DOLS), and Pooled Mean Group/AR Distributed Lag (PMG/ARDL) methods. FMOLS and DOLS provide only long-run estimates, while PMG/ARDL yields both long-run and short-run estimates. A key advantage of PMG/ARDL is its flexibility, allowing short-run dynamics to vary across cross-sections while maintaining invariant long-run coefficients. Extensions to FMOLS for panel data are proposed by Phillips and Moon (1999), Pedroni (2000), and Kao and Chiang (2000), while DOLS extensions are advanced by Kao and Chiang (2000), Mark and Sul (1999, 2003), and Pedroni (2001). The PMG/ARDL approach (Pesaran, Shin and Smith, 1999) adapts the cointegration framework of the ARDL model for panel data.

RESULTS AND DISCUSSION

The results of the unit root tests, though somewhat inconsistent, generally indicate that the variables are integrated, that is, they are non-stationary in levels but stationary in first differences (Table 1). Despite some discrepancies among the unit root tests, graphical analyses corroborate the hypothesis of non-stationarity. Overall, these series are confirmed to be non-stationary in their levels. Accordingly, panel cointegration tests are conducted.

Table 1: Panel unit root tests

Variables and tests	Level		First difference	
	Intercept	Intercept and trend	Intercept	Intercept and trend
Levin, Lin and Chu t*	Prob.**			
lnGDPpc	0.63	0.00	0.00	0.00
lnGAP	0.00	0.00	0.00	0.00
lnEPE	0.00	0.00	0.00	0.00
lnEPI	0.00	0.00	0.00	0.00
lnEPT	0.31	0.00	0.00	0.00
Breitung t-Stat.	Prob.**			
lnGDPpc	-	0.99	-	0.09
lnGAP	-	0.99	-	1.00
lnEPE	-	1.00	-	0.05
lnEPI		0.95	-	0.89
lnEPT	-	0.99	-	0.09
Im, Pesaran and Shin W-Stat.	Prob.**			
lnGDPpc	1.00	0.21	0.00	0.99
lnGAP	0.76	0.70	0.07	0.99
lnEPE	0.92	0.68	0.00	0.00
lnEPI	0.05	0.38	0.00	0.00
lnEPT	0.81	0.89	0.01	0.01
ADF - Fisher Chi-square	Prob.***			
lnGDPpc	0.99	0.02	0.00	0.00
lnGAP	0.64	0.83	0.44	0.00
lnEPE	0.86	0.99	0.00	0.00
lnEPI	0.01	0.12	0.00	0.00
lnEPT	0.69	0.99	0.12	0.09
PP - Fisher Chi-square	Prob.***			
lnGDPpc	0.94	0.00	0.00	0.00
lnGAP	0.00	0.05	0.42	0.00
lnEPE	0.56	0.00	0.00	0.00
lnEPI	0.00	0.00	0.00	0.00
lnEPT	0.51	0.72	0.05	0.00

Notes: * Heteroscedastic Consistent. ** Probabilities are computed assuming asymptotic normality. *** Probabilities are computed using an asymptotic Chi-square distribution. In the LLC, Breitung, IPS and Fisher-ADF tests, the automatic lag length selection is based on Schwarz information criterion with a maximum lag of 1. Moreover, to estimate the long-run variance in the LLC and Fisher-PP tests, the Bartlett kernel was used with maximum lags determined by the Newey and West bandwidth selection algorithm.

Source: Authors' calculations

The subsequent tables (Table 2 and Table 3) display the outcomes of Pedroni and Kao panel cointegration tests for distinct equations. It is evident that Pedroni's statistics partially reject the null hypothesis of no cointegration between variables, indicating that the long-run panel cointegration relationships between $\ln\text{GDPpc}$, $\ln\text{EPE}$, $\ln\text{EPI}$ and $\ln\text{EPT}$, as well as $\ln\text{GAP}$, $\ln\text{EPE}$, $\ln\text{EPI}$ and $\ln\text{EPT}$, could exist. On the other hand, Kao's panel cointegration tests reject the null hypothesis of no cointegration between observed relations indicating the existence of long-run panel cointegration relationships.

Table 2: Pedroni's and Kao's residual cointegration tests – equation (1)

Variables: lnGDPpc, lnEPE, lnEPI, lnEPT								
Pedroni test	Intercept				No intercept or trend			
	Stat.	Prob.	Weigh.	Prob.	Stat.	Prob.	Weigh.	Prob.
Panel v	1.19	0.01	-0.04	0.05	-3.36	0.99	-3.39	0.99
Panel rho	2.71	0.99	2.38	0.99	2.00	0.98	2.73	0.99
Panel PP	0.16	0.05	-3.41	0.00	-0.63	0.03	2.49	0.99
Panel ADF	/	/	/	/	/	/	/	/
Group rho	4.93	1.00	-4.95 /		3.96	1.00		
Group PP	-6.42	0.00			0.00			
Group ADF	/	/			/			
Kao test	t-Statistic				Prob.			
ADF	1.72				0.04			

Source: Authors' calculations

Table 3: Pedroni's and Kao's residual cointegration tests – equation (2)

Variables: lnGAP, lnEPE, lnEPI, lnEPT								
Pedroni test	Intercept				No intercept or trend			
	Stat.	Prob.	Weigh.	Prob.	Stat.	Prob.	Weigh.	Prob.
Panel v	-3.39	0.99	-3.39	0.99	-2.24	0.98	-3.21	0.99
Panel rho	2.13	0.98	1.92	0.97	1.17	0.09	2.31	0.98
Panel PP	-0.04	0.05	-1.99	0.02	-0.76	0.02	1.12	0.87
Panel ADF	/	/	/	/	/	/	/	/
Group rho	4.11	1.00	-3.61 /		3.82	0.99		
Group PP	-4.69	0.00			0.00			
Group ADF	/	/			/			
Kao test	t-Statistic				Prob.			
ADF	1.35				0.08			

Source: Authors' calculations

In order to gain a comprehensive understanding of the relationship between $\ln\text{GDPpc}$, $\ln\text{EPE}$, $\ln\text{EPI}$ and $\ln\text{EPT}$, here are the results from the relevant pooled and group estimations across different panel cointegration methods (Table 4). Pooled estimations from FMOLS, in general, provided a statistically significant and positive relationship between the variables in both cases, with no constant and no trend ($\ln\text{EPE}$ 0.02, $\ln\text{EPI}$ 0.08 and $\ln\text{EPT}$ 0.06) and with a constant ($\ln\text{EPE}$ 0.05, $\ln\text{EPI}$ 0.16 and $\ln\text{EPT}$ 0.02). Grouped estimations from DOLS indicated a strong statistical relationship with an expected positive sign in the case with no constant and no trend ($\ln\text{EPE}$ 5.49 and $\ln\text{EPT}$ 1.08, except for EPI -2.75 which was statistically insignificant), and statistically significant coefficients from the PGM/ARDL model ($\ln\text{EPE}$ 0.04, $\ln\text{EPI}$ 0.02 and $\ln\text{EPT}$ 0.04). Zero restrictions on the long-run parameters are tested using the Wald test, confirming their statistical significance (available upon request). Following the results, it can be concluded that an increase in environmental spending has a positive effect on socio-economic well-being in the observed European countries.

Table 4: Panel cointegration results – $\ln\text{GDPpc}$ (dependent variable)

Panel Fully Modified Least Squares (FMOLS) – (lags-leads; 1,1) – pooled estimation								
Variable	No constant and trend (FMOLS)				Constant (FMOLS)			
	Coeff.	Std. Error	t-Stat.	Prob.	Coeff.	Std. Error	t-Stat.	Prob.
$\ln\text{EPE}$	0.02	0.07	0.33	0.74	0.05	0.04	1.21	0.02
$\ln\text{EPI}$	0.08	0.03	2.63	0.01	0.16	0.03	5.72	0.00
$\ln\text{EPT}$	0.06	0.03	1.78	0.08	0.05	0.02	2.71	0.01
Panel Dynamic Least Squares (DOLS) – (lags-leads; 0,0) – grouped estimation Pooled Mean Group /AR Distributed Lag (PGM/ARDL)								
Variable	No constant and trend (DOLS)				Restricted constant (PGM/ARDL)			
	Coeff.	Std. Error	t-Stat.	Prob.	Coeff.	Std. Error	t-Stat.	Prob.
$\ln\text{EPE}$	5.49	1.67	3.28	0.00	0.04	0.01	5.48	0.00
$\ln\text{EPI}$	-2.75	1.89	-1.46	0.16	0.02	0.01	3.66	0.00
$\ln\text{EPT}$	1.08	0.60	1.80	0.08	0.04	0.06	20.85	0.00

Source: Authors' calculations

Similarly, when evaluating the relationship between $\ln\text{GAP}$, $\ln\text{EPE}$, $\ln\text{EPI}$ and $\ln\text{EPT}$, here are the results from the relevant pooled and group estima-

tions across different panel cointegration methods (Table 5). Pooled estimations from FMOLS, as expected, revealed a statistically significant and negative relationship between the variables in both cases, with no constant and no trend (lnEPI -1.66 and lnEPT -0.90; with lnEPE -4.45 being statistically insignificant), and with a constant (lnEPE -0.03, lnEPI -0.42 and lnEPT -0.06). Grouped estimations from DOLS offered a strong statistical relationship with an expected negative sign in the case with no constant and no trend (lnEPE -4.59, lnEPI -1.64 and lnEPT -0.94) and with a constant (lnEPE -2.67, lnEPI -0.63 and lnEPT -0.12), however statistically insignificant. The Wald test is used to examine zero restrictions on the long-run parameters, confirming their statistical significance (details available upon request). Based on the results, it can be concluded that an increase in investments, transfers, and expenditures in environmental protection narrows the gap between standard GDP and Green GDP, highlighting the importance of environmentally sustainable practices in selected European countries.

Table 5: Panel cointegration results – lnGAP (dependent variable)

Panel Fully Modified Least Squares (FMOLS) – (lags-leads; 1,1) – pooled estimation								
Variable	No constant and trend (FMOLS)				Constant (FMOLS)			
	Coeff.	Std. Error	t-Stat.	Prob.	Coeff.	Std. Error	t-Stat.	Prob.
lnEPE	-4.45	1.29	-3.43	0.00	-0.03	0.23	-0.15	0.88
lnEPI	-1.66	1.50	-1.10	0.02	-0.42	0.15	-2.83	0.01
lnEPT	-0.90	0.51	-1.77	0.09	-0.06	0.10	-0.56	0.05
Panel Dynamic Least Squares (DOLS) – (lags-leads; 0,0) – grouped estimation								
Variable	No constant and trend (DOLS)				Constant (DOLS)			
	Coeff.	Std. Error	t-Stat.	Prob.	Coeff.	Std. Error	t-Stat.	Prob.
lnEPE	-4.59	1.67	-2.80	0.01	-2.67	0.76	-0.35	0.73
lnEPI	-1.64	1.88	-0.87	0.03	-0.63	0.41	-1.55	0.15
lnEPT	-0.94	0.60	-1.57	0.09	-0.12	0.21	-0.57	0.58

Source: Authors' calculations

The consistency of results across various estimation methods and scenarios indicates a robust and stable negative relationship between national expenditure on environmental protection, environmental protection transfers, and total economy investments in environmental protection with the gap variable.

Namely, an analysis of 15 selected European countries reveals that an increase in environmental protection investments, expenditures and transfers contributes significantly to narrowing the gap between conventional GDP and Green GDP indicators. This alignment reveals the positive impact of dedicating resources to environmental protection, fostering a closer integration of economic indicators with sustainable environmental practices. The findings highlight an urgent need for governments to scale up investments in environmental protection while improving the efficiency of related processes, both in terms of inputs and outputs. Notably, heightened environmental protection investment within European countries can drive socio-economic safeguards of green economic growth, especially in nations prioritizing sustainability initiatives. Conversely, a significant positive relationship is observed between environmental protection investments, transfers, and expenditures, and GDP per capita on the other side, revealing the dual potential of environmental spending to advance both social welfare and economic prosperity.

In essence, there is a noticeable revival of the foundational principles of traditional economic growth policies. At the EU level, this trend becomes apparent through an analysis of the core elements of its green growth strategy, complemented by a review of the progression of both the national environmental expenditure index and the environmental protection investment index during the 2006-2019 period (Vavoura and Vavouras, 2022). These are the data, source and similar timeline that were observed through this analysis, therefore one has to be objective in conclusion. Vavoura and Vavouras (2022) suggested that this revelation brought about by the coronavirus pandemic represents the inherent fragility of this aspired green growth framework. The pandemic has underscored the vulnerabilities in balancing economic expansion with sustainable practices, emphasizing the need for more resilient and adaptive strategies to protect both environmental and economic objectives in the face of future crises.

However, conclusions from this study, as well as those of Čábelková et al. (2023), Yang, Gao, and Li (2022), Arjomandi et al. (2022), Batini et al. (2021), and Gallo and Ndiaye (2021) highlighted the indispensable role of investment and policy design in advancing environmental and economic objectives while enhancing societal well-being. This can be related to a few general conclusions arising from specific insight in these studies. Public support for environmental policies correlates with values of individual freedom and social equality. Governments can frame environmental protection as integral to quality of life and freedom to secure broader acceptance. Investments in clean energy and environmental conservation have demonstrated significant economic multipliers,

surpassing traditional non-green expenditures. Green spending can stimulate economic growth through job creation, innovation, and improved energy security while reducing environmental degradation. There are significant positive effects of government expenditures, particularly in R&D, green finance, and education. These investments boost green economic performance and well-being through innovation and labor productivity. Achieving a sustainable green economy requires coordinated government policies, targeted public spending, and incentivizing private investments in green infrastructure. Hence, governments should enhance fiscal support for green technologies, enforce long-term assessment mechanisms for environmental policies, and encourage regional collaboration for broader green transitions.

Based on the provided results and implications of the presented study, there are several concrete policy suggestions that the EU could consider in order to leverage these findings to enhance regional and individual country-level strategies. The first is to strengthen the investment in environmental protection, since this study highlights a positive relationship between environmental investments and GDP per capita, as well as their role in reducing the Green GDP gap. On the regional level, the EU could increase funding for cross-border green infrastructure projects (e.g., renewable energy grids or circular economy initiatives) and expand allocations within the European Green Deal, with specific sub-targets for sectors like biodiversity, renewable energy, and pollution abatement. On a national level, the EU could encourage national governments to introduce tax incentives for private investments in green technologies and implement public-private partnerships to develop green sectors and job creation. Next, since this study detects significant disparities in environmental protection expenditures across EU countries, EU policies could be more focused on reducing these disparities (for example, prioritizing environmental R&D investments in lower-performing countries to improve efficiency and foster innovation, and/or provide technical assistance for capacity building in underperforming regions, as well as provide grants for universities and private sectors to explore clean energy solutions). Finally, wider social support is crucial for ambitious environmental policies. On the EU level, there could be EU-wide campaigns to educate citizens on the benefits of green investments for both quality of life and economic resilience, and participatory platforms for citizens to contribute to environmental policy discussions. In addition, the EU could encourage local governments to host town halls focused on green transition benefits, and offer grants to NGOs that promote public awareness on green policies and practices. By implementing these targeted strategies, the EU could possibly optimize the socio-economic and environmental benefits

of green investments, ensuring a resilient, equitable, and sustainable future for its citizens.

The interplay among the variables related to environmental protection investment, GDP per capita as a variable representing universal socio-economic value, and Green GDP representing green growth aspiration, establishes a dynamic nexus that significantly influences the course of global development, societal well-being, and environmental sustainability. Central to this connection is the role of investing in environmental protection, which directly affects the health of the environment and, in turn, shapes the economic and social outcomes. Investments in initiatives such as pollution control, resource conservation, and renewable energy projects are intrinsically linked to Green GDP, an indicator that integrates economic growth with environmental considerations. This relationship displays the symbiotic bond between economic prosperity and ecological leadership, demonstrating that robust economic performance can align harmoniously with sustainable environmental practices (Tomić, 2024). Furthermore, this nexus transcends traditional economic indicators, embodying the broader principles of a green economy and sustainability. It highlights the potential for creating a balanced framework where environmental preservation serves as a catalyst for enduring economic and social advancement.

CONCLUDING REMARKS

At a time when the economy and the environment are facing unprecedented challenges, this research examines the complex relationship between investments in environmental protection and their effects on socio-economic well-being. The study analyzes the obstacles and opportunities that European countries encounter as they work toward achieving a sustainable balance between environmental health and economic stability, highlighting the importance of strategic action in shaping a sustainable future. The expanding body of research on the green economy reflects the growing global focus on sustainable development, environmental conservation, and climate change mitigation (Mo et al., 2024). As a development paradigm that harmonizes economic growth with environmental control, the green economy has become a central subject of scholarly and policy interest. It provides practical solutions to pressing environmental challenges, facilitates economic transformation and modernization, and addresses the public's increasing demand for an enhanced quality of life.

This study contributes to this growing literature by indicating, based on the sample of 15 European countries, that increased investments, expenditures, and transfers directed toward environmental protection play a critical role in reducing the disparity between conventional GDP and Green GDP indicators. This convergence highlights the transformative effect of allocating resources to environmental protection, promoting a deeper alignment of economic indicators with sustainable environmental practices. Moreover, a strong positive causal relation emerges between environmental protection spending and GDP per capita, underscoring the dual benefits of such investments. On the one hand, they contribute to advancing social welfare by addressing ecological challenges, and on the other, they drive economic prosperity, illustrating the multifaceted potential of environmental expenditures to foster both sustainable growth and societal well-being.

This study acknowledges several limitations, primarily stemming from the relatively short observation period due to data constraints for specific variables and countries. While the timeframe analyzed provides valuable insights into the key dynamics, extending the analysis over a longer period could yield more reliable and comprehensive findings. One can recognize that this research cannot fully address all aspects of international comparability regarding the growth perspectives among European countries. Differences in natural resource endowments, levels of economic development, sources of economic growth, and institutional capacities across regions pose challenges to drawing universally applicable conclusions. Consequently, the results presented are subject to a degree of uncertainty, partly attributable to data management limitations and gaps in understanding the national green growth initiatives. Future research efforts could offer greater contributions to the field by utilizing extended time series data and incorporating a broader range of countries. Such expanded analyses would enable a more thorough evaluation of the multifaceted impacts of environmental protection investments across economic, political, and social dimensions, providing valuable insights into the global implications of sustainable development practices. Future research should also prioritize the development of standardized methodologies for calculating Green GDP, ensuring greater consistency and comparability across studies and regions. Efforts should also focus on enhancing the availability and quality of data, addressing critical gaps that currently hinder comprehensive analyses. Moreover, it is essential to tackle the inherent subjectivity involved in assigning monetary values to environmental goods, striving for more objective and universally accepted valuation techniques. In addition to methodological advancements, further empirical stud-

ies are needed to evaluate the practical applicability of Green GDP across diverse economic contexts.

Even though environmental externalities, market failures, different political ideologies, conceptual, technical and ethical issues complicate the comprehension of the green growth and socio-economic wellbeing, this modelling approach can be used within conventional growth modelling to scale the sustainability of economic progress – namely, it can offer a more comprehensive understanding of how economic development can be harmonized with environmental maneuvering through investing in environmental protection, ultimately fostering long-term human welfare.

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**WATER ECONOMICS
and WASTE MANAGEMENT**

ECONOMIC VALUATION OF WATER RESOURCES – A CASE STUDY ON THE CATCHMENT OF LAKE VELENCE, HUNGARY

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The negative effects of climate change have made water the blue gold of the 21st century. Water is essential for human existence, and due to the changing environment, it has become a scarce natural resource. Hot, dry summers, which are becoming more frequent, significantly increase the length and frequency of drought periods, and thus increase the need for irrigation in agriculture. Watering plantations is essential to maintain food security, and in addition to limiting the water resources, it reduces access for other water users. As a result of this, in the summer season, the water availability of the reservoirs and the water level of the lakes are lower, which negatively affects tourism, recreational opportunities and the availability of water sports.

Distributing water resources among potential water users results in conflicts, and solving these issues is considered to be the task of water professionals, although this is a multidisciplinary assignment. The cooperation of stakeholders and social involvement, as well as maintaining a good status of the environment, and providing an overall economic assessment are part of the evaluation process. Determining the value and util-

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ity of water differs depending on the time, place, and application. Good water management can contribute to economic growth, social well-being, proportional distribution of water in scarce years, and thus to the reduction of water related conflicts. By determining the value of water, decision makers receive a tool to create a thoroughly considered and well-founded water distribution method which, if necessary, can serve as the basis for sustainable water replenishment solutions.

The water resources of the catchment of Lake Velence, despite the surrounding partly hilly territorial character, have limited replenishment. Extreme drought periods over the last few years have resulted in record low water levels in the lake and increased water-related conflicts. A questionnaire survey was conducted among water users in order to determine the value of water, and 840 responses were obtained. In addition to creating an overview of the physical condition of the water resources in the watershed, their willingness to pay for better/more water was also assessed. In both cases – the improvement of the amount and/or the quality of water – responders were asked about their willingness to contribute either occasionally and/or on an annual basis. The respondents were divided into three large groups: permanent residents, temporary residents and tourists. More than one third of all respondents considered the adequate quantity and quality of water to be a state task, so they did not want to make any further financial contributions above the taxes that are already being paid. On the other hand, the great majority – almost 2/3 of people – would support these efforts from their own wallets. Based on the sums of their payment contributions, considering water as a different economic good, we determined the value of the water unit belonging to the current state, among the different water users.

Knowing the value of water among all water users of the watershed allows decision makers to distribute the scarce water resources based on economic assessments, and to fairly compensate those stakeholders that suffer losses due to water reallocation. Furthermore, in case of investment decisions, the extent of the contribution by the actual water users with their beneficiaries can be determined. Using this valuation methodology, even though water is a public good, the individual benefits and advantages achieved by having surplus due to water redistribution or replenishment, or better quality of water, can be quantified. The value function of water is a complex function with many variables, therefore its determination can support detailed, cross-sectoral economic assessments and can be transformed to investment decisions. Furthermore, stakeholders

suffering losses due to the scarce or reallocated water resources, e.g. in extreme drought summers, can be compensated from the profits of gaining stakeholders.

Keywords: *Water management, economic benefits, water valuation, stakeholder cooperation, sustainability*

JEL classification: *D74, D81, H41, Q25, Q51*

INTRODUCTION

Water is a crucial and indispensable natural resource and has become the blue gold of the 21st century due to the negative effects of climate change. Water is an essential and irreplaceable element of human existence, a significant actor in society, economy and environment (UN, 2024). During the previous centuries, water was considered a non-excludable, non-rival natural resource, a pure public good (Zaag & Savenije, 2006). Due to the changing environment and its uses, it is increasingly emerging as a scarce resource both in space and time (Tietenberg & Lewis, 2023). As a negative effect of climate change, the drier summers are more frequent and they last longer, with an increasing number of temperature extremes which significantly increase drought periods and water demands. In order to compensate for the increasing evaporation which is the result of the rising average temperature, it is necessary to intensify the amount of irrigation to maintain the level of agricultural production and sustain the crop yield (Arora, 2019). With the constant or decreasing amount of water resources available in an area, and the increasing need to irrigate agricultural areas to maintain food security, some water users are forced to tolerate limited access to water. This shortcoming may lead to conflicts among stakeholders and water users (Kálmán & Bene, 2024). Summer droughts result in reduced water resources, including reduced soil moisture and water levels in reservoirs and lakes. This unfavourable progress is observed in the catchment of Lake Velence, where these adverse effects have resulted in a decrease of the lake water level. They also affect tourism, lakeshore and catchment-level recreational opportunities, and the accessibility of water sports, including fishing, angling and even farming (Kék Bolygó, 2022). Freshwater lakes and the connected ecosystems can generate income, and these ecosystem services have been valued from several viewpoints, but water and its direct value, which actually creates the values for lakes, the surrounding landscape and the wetland ecosystems, have not been determined (Grande et al., 2023).

The allocation of water resources is a complex task, which, in normal times, is carried out by water professionals and can meet all the user needs. Due to the decreasing water resources, its allocation cannot be fully implemented, thus creating conflicts among potential water users as the supply of several demands turns out to be uncertain (Kálmán et al., 2024). Solving the allocation of scarce water resources is no longer necessarily the task of water professionals alone, as water management requires a broader decision-making process and a multidisciplinary approach (Tian et al., 2019). An efficient and fair allocation necessitates the awareness of user needs and the cooperation of various stakeholders, all in the light of sustainability objectives. This includes a balanced development among the three key areas: social engagement, interventions that ensure preservation, a good state of the environment, and a comprehensive economic assessment (UN-Water, 2016).

The value and utility of water are different, and even the value of the same water molecule can vary greatly over time, by place, and depending on the nature of its use. This greatly depends on the nature of water as an economic good, and on the supply-demand balance of the available resource (Ahmed et al., 2018). Water can have all the properties on a wide interval scale between a private good and a pure public good. In a bottle of mineral water, the water is clearly private property, and only the owner who bought it can control its consumption, excluding everyone else. Ownership is acquired through a sale-purchase transaction, at a price corresponding to the pure market supply-demand balance, after which the quantity of the stock available to the seller decreases (Zeder, 2024). In contrast, water in a lake or on a public beach is public good, its quantity does not decrease as a result of use – bathing, swimming, sailing, boating, etc. – and the water user cannot exclude others from its consumption (White, 2015). When the water needs (demand) exceed the available water resources (supply), which has also been observed in the studied area in recent years, water begins to function as a so-called common good with mixed properties. Climate change exacerbates and lengthens the summer drought periods and negatively impacts the precipitation events, resulting in more severe water shortages and arising conflicts among stakeholders in the future. Partly due to greater evaporation (decreasing supply), and partly due to the increasing number of water users (increasing demand), water is turning into a scarce natural resource. Regions therefore either accept the unnecessary and negative landscape transformation due to the decline of wetland areas or prepare appropriate water resource management and water distribution plans to overcome the negative impacts of elongated dry summer periods (Gownaris et al., 2018). As the free and unlimited usability characteristics of water have

remained, it is considered as a pure public good, although this “overconsumption” excludes several water users from fully satisfying their needs. For them, the consumption of the scarce resource in its use by other water users as a public good appears as a negative externality, and they experience water resources as a tragedy of the commons (OECD, 2024). In creating sustainable and feasible water replenishment solutions, it is inevitable for decision makers to know the value of water for the purpose of investment payback calculations and evaluation of possible future developments. The water value function is very complex, and depends on many variables: the type of user, location, time, availability, quality, water use need etc., as well as on the subjective judgement of stakeholders. In addition, water is a vital element, essential for human existence. Access to water, clean drinking water and sanitation is a vital human right, which is set in the 2010 UN statement (UN, 2010). Accordingly, the preference curve for water has a unique shape, and near the smaller demand volumes it becomes inelastic in short increments, both in exchange for any other product and in terms of price.

As water becomes a scarce natural resource, rivalry rises among users, which causes negative externalities for some actors and results in conflicts. Therefore, the development of good water management is of key importance, and can contribute to the economic growth of a certain settlement or region and to social well-being in scarce years. In addition, a proportional and fair distribution of water resources can reduce conflicts between water users. By determining the value of water, the benefits to be generated by the different water uses and users can be quantified, which helps determine the efficient distribution of the scarce resource (Eiswerth et al., 2000).

One method of measuring the utility of water is the water value-based approach. The difficulty is that the indifference, and thus the demand curve for water, is not universal and varies from region to region depending on the different environmental conditions, the local social habits, and the diverse needs of water users. Previous research has examined either the monetary value of freshwater lakes as a natural asset, or the value of lakes ecosystem services globally. The results obtained in terms of freshwater lakes globally stated that the monetary value is USD 87-340 trillion for the lifetime, and USD 1.3–5.1 trillion as annual ecosystem services (Li et al., 2024). The total freshwater volume in lakes amounts to approx. 182,000 km³, which translates to approx. 0.5 USD/m³ in monetary value and 0.02 USD/m³ in value from ecosystem services (Messenger et al., 2016). Our study focuses on the value creating ability, i.e. income and GDP generating potential, of each unit of water as the function of water users’ perception, determined by quantifying individual responses. In

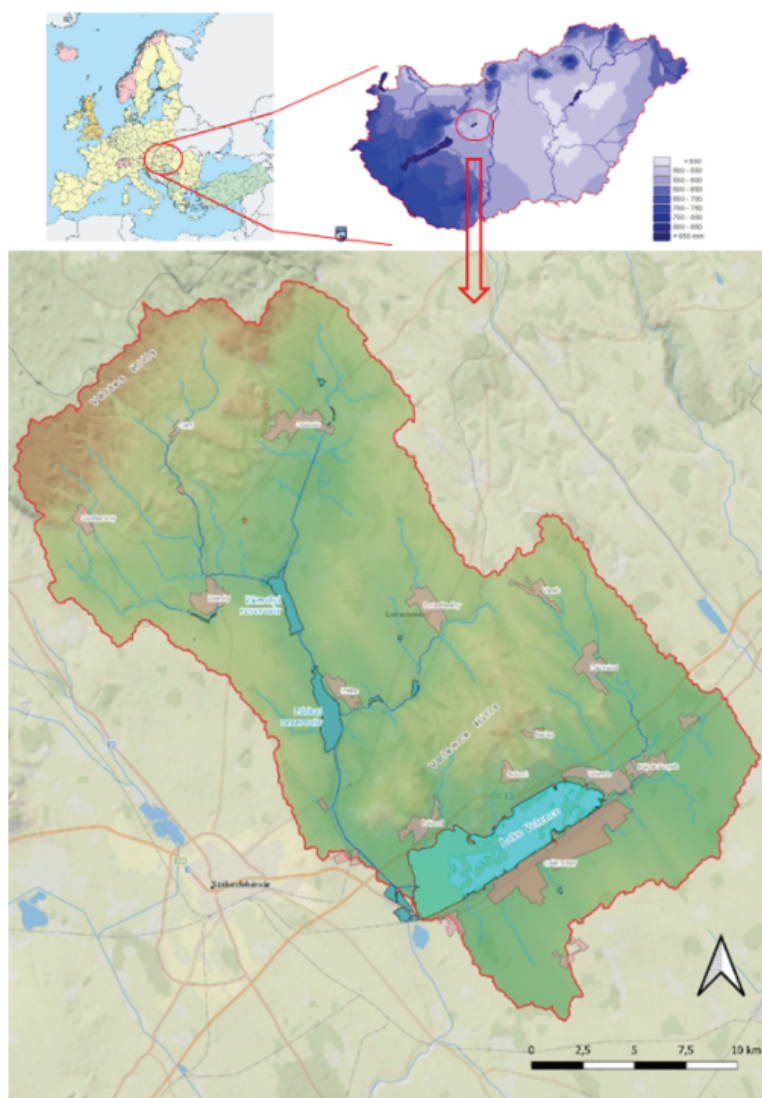
this study, we create the aggregate demand curve of water users in the Lake Velence catchment area based on the responses to an online questionnaire survey, using the willingness-to-pay (WTP) method (Széchenyi Egyetem, 2024). The unit value of water is a non-linear continuous function that can determine the value added or income generated by each additional water unit while taking into consideration the externality cost of relocation or expenditure of replenishment. The aim of the method is to be able to draw the water demand curves in any other freshwater areas, thus being suitable for supporting efficient and fair distribution decisions for scarce resources such as water.

METHOD

SITE DESCRIPTION

Lake Velence and its catchment are located in the Central Transdanubia region of Hungary (Fig.1.), near the capital city, Budapest. Despite its relatively small size, the catchment is a diverse region, with a diversified, spectacular landscape and rich aquatic ecosystem. There are both flat and hilly areas, including the most stable and oldest rocky mountains of Hungary. The central part of the 602.3 km² watershed is Lake Velence, with a surface area of 24.2 km². It is a shallow, saline lake with an average 150 cm water depth and large water level fluctuations throughout the year (OVF, 2024). Unfavourably, the long trend (1986-2020) of the lake water balance shows a water level decline, with an average of 1cm annually (rain over the lake + 54.8 cm; inflow from catchment + 32.3 cm; inflow from reservoirs + 14.9 cm; evaporation - 91.3 cm; drainage-outflow - 11.7 cm). Furthermore, a significant water level decline has been observed since 2020, and on 23 September 2022 the lake water level reached its record low with a depth of 53cm. Although over two years have passed, the water level has still not returned to the minimal required level of 130 cm.

Figure 1: Catchment area of Lake Velence



Source: Top – country precipitation map: www.met.hu; bottom – catchment map: Author

This area has significant economic potential and has seen dynamic population expansion in the past two decades. The land use and landscape have changed. A high-speed railway line and the only 3-lane motorway section in Hungary were built right next to the lake. In addition, these major infrastructures border the lake on both sides of the two longer banks, thus limiting the

possibility of natural water level fluctuations and water storage in the surrounding areas. As a result of the more developed infrastructure, the area has become a popular tourist area, offering from a few short hours of recreation or relaxation up to longer, even week-long stays. Due to its proximity to the big city nearby, the population around the lake has doubled in less than three decades, which has also had a negative impact on water resources (KSH, 2024). The changing land use and landscape, the expanding water demands, and the negative effects of climate change together are causing significant and inevitable changes in the local water cycle.

Due to the declining water resources, water-related conflicts have intensified in the Lake Velence catchment. Simultaneously with the increasing number of users, the water demand has also increased, as have the requests for water-related services. The extreme drought has therefore led to severe water shortages in the entire catchment, which has resulted in large-scale conflicts among water users. The summer evaporation of Lake Velence is significant. On hot summer days, it can be as high as 1 cm per day and lake surface evaporation is responsible for 86% of the total water loss (KDTVIZIG, 2024). Climate change is intensifying the extremes. The number and length of summer drought periods are expected to increase in the coming decades, which further increases evaporation by up to 8%. This will result in additional 6-8 cm of water level decrease annually, equaling to a loss of 1.5-2 million m³ of water resources.

RESEARCH METHOD, WATER ECONOMICS

The Lake Velence region is a popular angling and recreational area. In order to understand the current conditions, the Water Research Group of the Széchenyi István University conducted a public online questionnaire to learn about the perceptions, opinions and needs related to water use. The title of the research was “Lake Velence: Values, Problems, Future Visions”, and the aim was to learn about the current water related issues of Lake Velence and to map the needs of the various water users in order to sustainably improve the water management strategy. The questionnaire was available online for 2 weeks (between July 26 and August 11, 2024) (Kálmán, 2024). The evaluation of catchment-scale water-related needs and challenges was done using 1-5 and 1-7 Likert scales, with the possibility of providing personal explanatory notes. The opinions of locals and short-term visitors were collected and compared in order to understand the requirements of the ecosystem services. In addition to the subjective perception of water quantity and water quality, significant emphasis was placed on examining

the value of water among the water users. The methodology used for this was based on the “willingness-to-pay” examination of water resources. Each respondent had the opportunity to provide their own estimate – based on their personal perceptions – and determine the level of available water resources and their quality. In order to assess the individual willingness to improve the currently perceived status, two financial options were offered for both quality and quantity. The respondents could contribute to improvement on a case-by-case basis and with an annual fee. In case of the case-by-case basis, the values were listed from 0 to 2.000+ Hungarian forints on a 9-point scale (equivalent to 0 to 5 euros) for a two-stage improvement in a particular characteristic. The values in the 9-point scale for an annual contribution were listed from 0 to 20.000+ Hungarian forints (equivalent to 0 to 50 euros). The obtained individual willingness-to-pay insights and the personal preferences thus allowed for the construction of a water demand function, which enables the economic evaluation of water-related services among various water users and stakeholders.

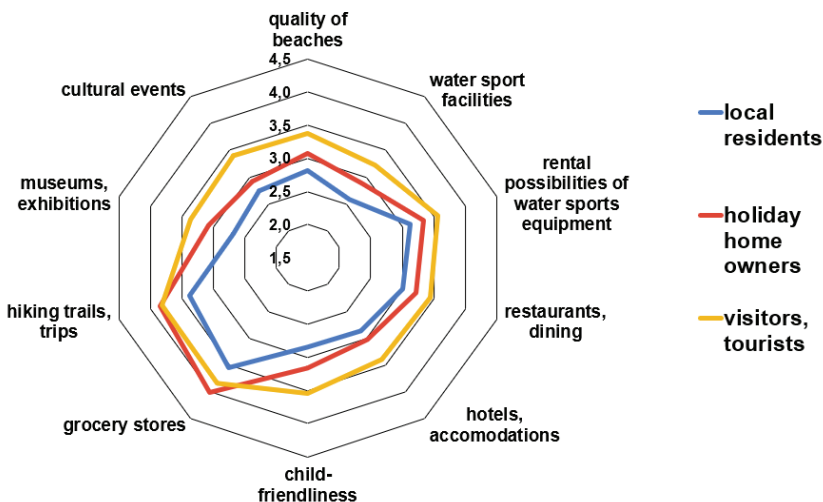
RESULTS

The questionnaire was completed by 840 people from 89 different settlements. About half of the respondents (48.1%) were from the lakeside settlements, and 57.4% live in the watershed. Regarding the wider environment, about 2/3 of the respondents (67.3%) are Fejér county residents, while 1/3 (32.7%) live outside the county, which shows the high interest and strong connection to the lake and its catchment. At the time of completion, significant online activity was observed, while various information exchanges of ideas and personal feelings developed on several different forums regarding the questionnaire and its study topics. Additionally, the detailed and extensive completion of the optional text comments appearing in the questionnaire also confirmed the importance of the research. These personal opinions were constructive, with a wide range of information related to the lake and its catchment. The respondents were divided into three groups: local residents (57.3% of respondents), temporary residents, people with holiday homes (18.8% of respondents) and visitors, tourists (23.9% of respondents).

The waterfront environment contains many opportunities and diverse problems. These are partly due to the changing environment caused by climate change, and partly due to the dynamically expanding population and the infrastructure developments closely related to it, but they are also caused by the different water use goals of individuals, different water user needs and

activities. The lake and the watershed provide opportunities for a wide range of activities and programs, e.g. sports, relaxation, beaching, recreation, fishing, cultural events, etc. The available services were rated on a traditional scale of 1-5 and overall, the result was a medium (3.18) value (Fig.2).

Figure 2: *Quality of services – based on questionnaire responses*

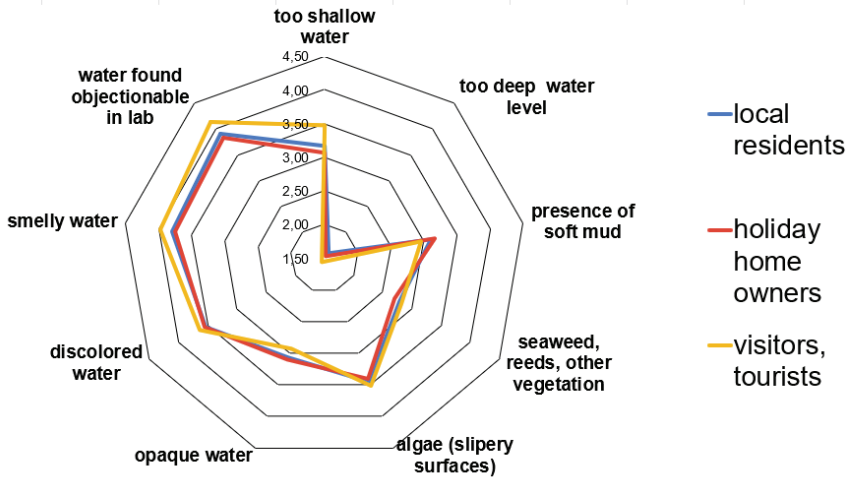


Source: Author

There are, however, significant differences between the quality assessments of different services, with more than one point difference between the best and worst service. Partly contradictory, out of all the services available around the lake, only hiking and grocery stores – which are not directly connected to water – were rated good (4). Services directly related to water, such as the quality of beaches (2.99) and the condition of water sports facilities (2.79), did not even reach the medium level among the respondents. Overall, the local residents rated all services a few tenths lower than the visitors, while the holiday home owners' judgement is mostly between these two values.

In addition to the general quality problems of services, respondents could also rate the obstacles they perceived during water use on the same traditional 1-5 scale, where 1 stands for "Not typical, not a problem", and 5 is "Typical, a serious problem". Despite the diversity of water users, quality problems were mainly identified as the biggest obstacle by the respondents (Fig. 3.). The three largest obstacles were poor water quality – laboratory tested, discoloured water, and smelly water.

Figure 3: Perceived obstacles in water use, based on questionnaire responses

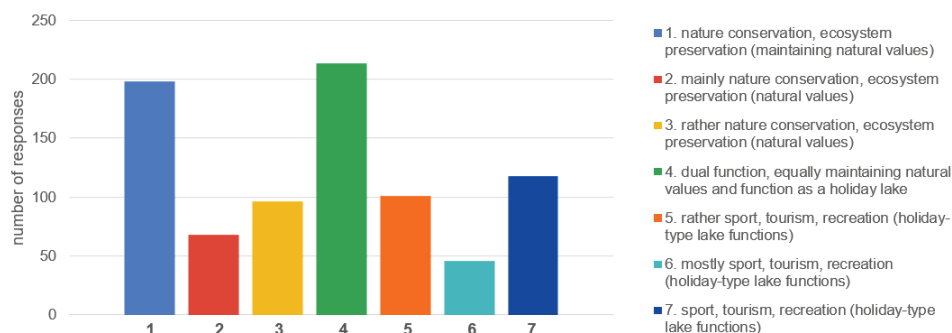


Source: Author

The three investigated groups perceived the diverse obstacles quite similarly, with slight differences – besides the water level – observed only in the perception of the odour of the water and the results of laboratory testing. Despite the fact that visitors and tourists rated the quality of services the best, this group also highlighted the perceived obstacles the highest, rating them a few tenths more severe than the locals.

The area has been severely affected by the extreme droughts of recent years. As a result, the water level has become record low and dropped to 53 cm on 23 September 2022. This is approximately 100 cm (~25 million m³) lower than the average water level and about 70 cm lower (~17 million m³) than the average water level in September. Therefore, most water users have faced various difficulties and obstacles for a few years, as the water level has still not fully recharged. The watershed has already had challenges maintaining the water balance in the past, but due to climate change, these extremely low water levels are expected to become more frequent in the upcoming years of the 21st century. For this reason, and without significant water replenishment to recharge water levels in drought years, it is necessary to examine if there is a priority function of the area, the environment or the recreational water users. Avoiding water restrictions, large-scale regulated water replenishment could be an option, but this involves significant costs that need to be financed by some stakeholder(s).

Figure 4: Desired main function of the area – based on questionnaire responses



Source: Author

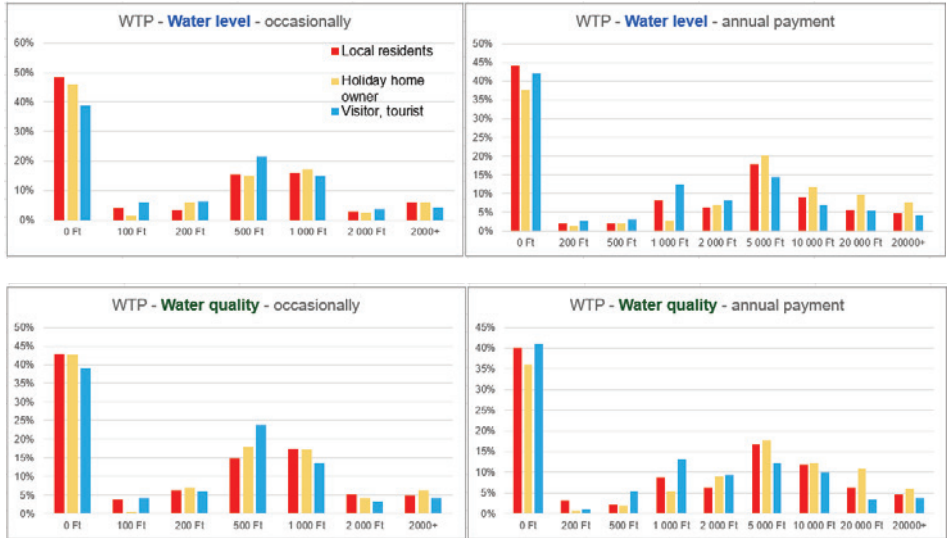
The Lake Velence area provides two main functions: A. wetland, natural environment; and B. water tourism, sport, recreation, fishing, holiday lake. In case of scarce water resources, it may be necessary to set a priority between the two functions so that the water demands can be fulfilled in a sustainable way and provided in the long term, even in changing climatic conditions. The distribution of answers between the two functions is shown in Fig. 4. Nature conservation and ecosystem preservation, i.e. maintaining natural values (column #1, light blue) represented a significant proportion of the answers. In contrast, sport, tourism, recreation, i.e. the holiday lake function (column #7, dark blue) received less votes. The largest portion of the respondents would like to preserve the dual function of the area (column #4, green), i.e. nature conservation, ecosystem priority and sport, tourism, recreation, and holiday purpose of the lake have identical priority among the received answers.

The survey clearly revealed that the water level of recent years has fallen below the ideal level, as the different respondent groups gave very low values (on a 1-5 scale) for the water level satisfaction question: local residents scored 2.13, those with their own holiday homes 2.16 and visitors and tourists 2.64. As a result of the significant improvement of water resources in 2024, the personal judgment of the water level (on the 1-5 scale) increased by 1-1.5 grades in the 3 different groups. The assessment of local residents increased to 3.66, those with their own holiday homes to 3.90, while the assessment of visitors and tourists increased to 3.71. Despite the “perceptible water level increase” in 2024, the water resources and thus the lake level are still “significantly below the desired level”.

The climate models predict that the length and frequency of hot, dry summer periods will increase in the upcoming decades, which could lead to inter-

mittent or even multi-year water shortages in the catchment of Lake Velence. The diversity of water users makes it increasingly difficult to fairly and equally allocate the available water resources. Deterioration of water resources is a significant source of conflicts among the water users, and therefore with the rising competition and stakeholders, the water progressively loses its role as a public good. Its unlimited nature is disappearing, its common consumption and common utility are impaired, and its marginal utility is declining. As it becomes a common good or in some situations even a private good, its public financing and full provision are about to change. At the same time, low water resources are triggering competition among water users to continue to benefit from the scarce resource, in addition to the usual free supply. The majority of water users are not state organizations or individuals, therefore the willingness to pay attitudes of these users/stakeholders were part of the questionnaire and were assessed among the respondents. The willingness-to-pay method was used to determine how much the person is willing to pay (a self-reported subjective judgement) to improve his/her current personal satisfaction with the water level/water quality by 2 grades – either to get a higher water level or to get better quality water. Fig.5 shows the responses to the payment willingness.

Figure 5: Payment willingness for better quality of water/higher water level in the lake – based on the questionnaire responses

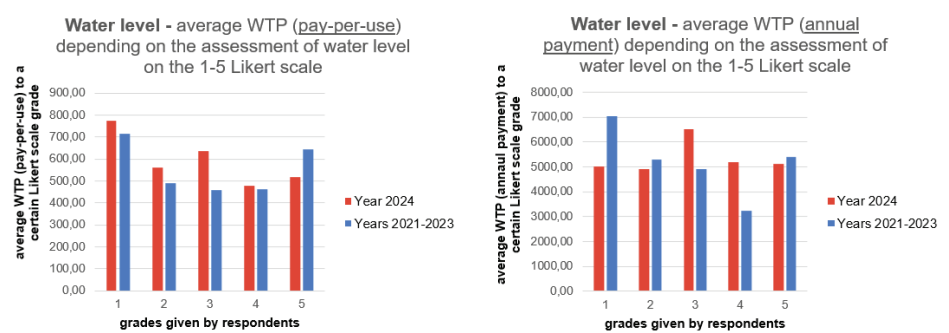


Source: Author

On the left, the occasional amount of daily payment is shown in terms of water quantity (top) and water quality (bottom), while the figures on the right represent the values in the case of annual payments. The annual values are approx. 10-fold higher than the occasional payment values. Values are given in Hungarian forints, which is the national currency of Hungary. This can be exchanged to euro, and 1 euro equals 410.09 forints (the official exchange rate of the Hungarian National bank was 410.09 Ft/euro on 31 December 2024). The occasional average payment willingness is in the range of 1-2 euros in both cases and the average annual payment willingness is approximately 10-15 euros in both cases. For the purpose of water level improvement, about 52%-57% of the respondents showed a willingness to pay while the other respondents believed that it is a state task. For water quality improvement, a slightly higher percentage of the respondents showed willingness to contribute financially, approx. 57-61%, and about 2/5 assumed it was a state task.

The distribution of payment willingness – in terms of water level – among the 5 grades of the Likert scale was nearly even in the year 2024 when the water level was partially recharged compared to the previous years (Fig.6, red columns). The evaluation shows different results than when the water levels were lower, as in the years 2021-2023 (blue columns), and the distribution among amounts of payment willingness varies noticeably based on subjective assessments, and shows larger fluctuations among different grades. There are more intense differences in the willingness to pay in the case of an annual lump sum contribution.

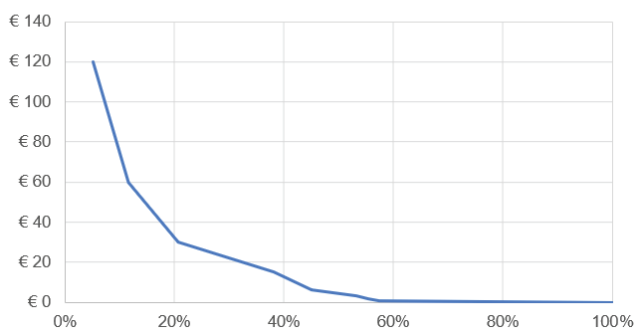
Figure 6: Payment willingness depending on a personal assessment of water levels – based on questionnaire responses



Source: Author

The decreasing water level in Lake Velence and the reduction of water resources in the catchment due to climate change, require adaptation. Water users are dissatisfied with the quantity and quality of the available water. All participants in the questionnaire consider these problems serious, to the extent that the large majority of the respondents are willing to take appropriate steps to replenish water and improve the water quality. The various answers to the willingness-to-pay questions showed that the water users would be cooperative – individually or locally – in order to supplement the present state/central governmental financial budget. Improving the current situation is a common interest and the area is important enough for the participants to make a personal contribution to counterbalance the deterioration of the service level caused by external impacts such as the negative effects of climate change. By rearranging the amounts showing the individual willingness to pay presented in Fig.5 and Fig.6, and summing up the values of the different grading categories, the demand curve of water users can be drawn. The demand curve representing the number of people in the 5 categories (1-5 Likert-scale) and the amounts they are willing to pay for better service level is shown in Graph 1.

Graph 1: Water demand curve for water level improvement (function as of level improvement) – based on questionnaire responses; maximum willingness-to-pay for a 2-grade improvement on the 1-5 ranking



Source: Author

The value of water can be measured through the economic benefits generated by its utilization among the different water users. The appropriate water quality and water levels support lakeside tourism, which, for example, increases the sale of beach tickets, revenue from the buffets, restaurants, etc. Recreational and holiday tourism is related to e.g. the number of guest nights spent in hotels and apartments. The sale of fishing tickets and the income from fish-

ing also provide a good quantification of the economic benefits of a given area. Similarly, the number of birds, the diversity of protected animals and natural values, the output of fish farms, and the impacts of forests on the natural environment can all be quantified. The demand function of water can lead through these different areas of use to the distribution of this scarce natural resource with the highest utility, based on a multi-dimensional optimization of the water allocation process. Presently either freshwater lakes or their connected, surrounding ecosystem services are valued, but not the water itself that directly or indirectly generates values for lakes and their environments. In the study by Eiswert et al., the estimated values were between USD 12-18 per person annually for a 1-foot rise in lake water level. Although the method is different, the results are similar to our findings. The tasks for the upcoming period are to validate the presently constructed demand function and to determine the value-added functions of the different water users. Furthermore, the task is to create a universally applicable method that is suitable to be used for the subjective perception of individuals on lake water level in order to construct a polynomial function that describes the connection between water level of a lake and the profit generated by that lake at a certain water level. The next steps in the future are to create utility and demand functions of water in a particular lake, and create the connection between lake water level and additional benefits, i.e. generated profit. For example, in case of a water shortage, the cost of water replenishment and the possible additional income generated by higher water levels (or the lost profit due to lower water level) could be calculated for a given lake to support a real decision-making process. The method is a water management development activity in which a broad range of stakeholders are included for the purpose of consensual agreement regarding water distribution among the potential users.

CONCLUSION

The changing water cycle induced by climate change has negative impacts on individuals, as well as at catchment-scale levels. Adaptation requires the broadest involvement of stakeholders in order to sustainably and fairly allocate the water resources. The aim of our questionnaire survey was to learn about the problems and needs of the different water users, both on the individual, and on the local community, catchment levels. The operation and maintenance of public goods – such as Lake Velence and its surroundings – is fundamentally a state task. According to this practice, the financing of Lake Velence water

management comes from the central government, from the central budget to the local water management directorate, which takes care of the operation and maintenance duties. In contrast, local governments and those who directly use water do not contribute to better services such as more water (higher water level) or better water quality. The services provided by the water resources in recent years have only partially met the requirements of the water users' needs in terms of quality and quantity, which is the cause of the rising conflicts in the catchment of Lake Velence. The results of the survey confirm that approximately 3 out of 5 water users would be willing to personally make a financial contribution so as to obtain higher service levels. The scale of the payment willingness varies, but the contribution itself shows typical trends. Based on the collected responses, the characteristic demand function of different water users could be composed, both in terms of water quantity and water quality. Using these functions of the various water uses, the cost-benefit equilibrium points of water user groups and water values can be determined. In the case of scarce natural resources like water in the changing climatic environment, the exclusions of water users can be determined. The order of restrictions and exclusions can be based on economic valuations, considering ecological constraints, in such a way that would preserve economic growth and prosperity.

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REDUCING FOOD WASTE IN HUNGARY: A STUDY OF CONSUMER ATTITUDES AND SUSTAINABLE PRACTICES

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Food waste represents a critical issue with significant environmental, social, and economic impacts. While academic research has addressed food waste from various perspectives, there is still much to be understood about consumer attitudes, particularly in Hungary. Consumer-level food waste presents challenges to environmental sustainability and resource efficiency, necessitating the implementation of targeted strategies to minimize waste. The objective of this study was to gain insight into Hungarian consumers' attitudes towards food waste, with a particular focus on the food categories most affected, the underlying reasons for waste generation, the associated emotions, and potential recycling practices.

In December 2023, a quantitative online survey was conducted involving 231 respondents. The findings indicate that food waste among participants is relatively low, with the majority of waste produced referring to perishable items such as milk, bread, and cooked food. The primary causes of food waste are the purchase or preparation of excess food items and food items that have reached their expiration date before they can be consumed. The respondents indicated that they experienced a range of strong emotional responses, including regret, guilt, anger, and remorse, when discarding food. A significant factor motivating respondents to reduce waste was the financial loss associated with discarded food.

It is encouraging to note that the majority of respondents demonstrated sustainable behaviors by recycling leftovers. This included repurposing them in meals, feeding them to pets, or composting. These results

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highlight the need for increased awareness and promotion of sustainable food consumption practices. The study's findings underscore the need for practical guidance from industry, government, and non-governmental organizations (NGOs) to empower consumers to plan their meals more efficiently, thereby reducing food waste.

By gaining insight into consumer attitudes and behaviors, this research contributes to the broader goal of reducing food waste. It offers actionable insights for policymakers and stakeholders in the food supply chain, which can be used to foster environmental sustainability and resource efficiency.

Keywords: Food waste, consumer attitudes, sustainable food consumption, consciousness

JEL classification: D12, M31, Q01, Q18, Q53

INTRODUCTION

Food waste is a critical global challenge, with an estimated 1.05 billion metric tons generated annually in the retail, food service, and household sectors (Fleck, 2024). Within Europe, Germany leads the way with over 6 million metric tons of household food waste annually, followed by France and the United Kingdom (Tieso, 2023). Hungary produces approximately 908,669 metric tons per year, which is equivalent to an average of 59.85 kg per capita in 2022 (Medve, 2023).

The composition of food waste varies by region, with fruit and vegetables accounting for 25% of food waste in Hungary, followed by bakery products at 18% (Medve, 2021). Ready-to-eat meals are also a significant contributor to waste, at 10.6 kg per capita per year (T. Ozbun, 2024). In order to mitigate the rising food prices, many European consumers are focusing on reducing food waste at home, with 61% of Portuguese respondents reporting this strategy (T. Ozbun, 2024). In Hungary, the share of the minimum wage spent on basic food reached 23.9% in January 2024, highlighting the economic impact of food costs and waste (Medve, 2024).

Globally, initiatives to reduce food waste are making progress. For example, Mondelez International reported a 28% reduction in internal manufacturing waste and a 69% reduction in distribution waste by 2023 (Alves, 2024).

The objective of this study is to examine consumer attitudes toward food waste, a subject that has been extensively investigated globally but remains un-

der-researched in Hungary. As an initial exploratory study, it aims to identify the principal behaviors, emotions, and practices associated with food waste among Hungarian consumers, thereby establishing a foundation for more comprehensive, descriptive research in the future.

This research is of significant importance as it addresses the critical issue of consumer-level food waste, which has substantial environmental, social, and economic consequences. By focusing on Hungary, where consumer attitudes and behaviors toward food waste are not well understood, the study fills an important knowledge gap and provides valuable insights into the factors driving waste generation and sustainable practices. The findings of this study can inform the development of targeted strategies by policymakers, businesses, and NGOs to reduce food waste, promote sustainability, and improve resource efficiency at the consumer level. The primary contribution of this research lies in its ability to inform targeted interventions, support sustainability initiatives, and enhance food waste management strategies, with a particular emphasis on Hungarian consumers.

The remainder of the paper is organized as follows: Section 1 presents a review of the existing literature and outlines the research questions to be addressed. Section 2 delineates the methodology employed to address these questions. Section 3 presents a summary of the findings from the study. Section 4 presents the findings, and Section 5 concludes with an analysis of the study's implications, limitations, and suggestions for future research.

THEORETICAL BACKGROUND

Recent research highlights the multifaceted dynamics of attitudes, behaviors, and policy preferences related to food waste.

Studies show generally positive attitudes toward reducing food waste, especially among younger demographic groups. For example, young Saudi women express strong preferences for food reuse, redistribution, and recycling (Malibari et al., 20-23). Similarly, environmental awareness among Generation Z in Indonesia strongly influences their commitment to waste reduction (Purwanto et al., 2023).

Despite high levels of awareness, there is a gap between knowledge and action. Green consumers in Ireland often waste food due to spoilage or negligence, despite valuing sustainability (McCarthy & Liu, 2017). Similarly, in Serbia, individuals who reported minimal waste were found to discard significant amounts, indicating a disconnect between self-perception and behavior (Janjic et al., 2019).

Demographic differences significantly shape attitudes. In Ireland, older women are more concerned about reducing waste than younger men (Flanagan & Priyadarshini, 2021). Croatian university students vary in their knowledge and willingness to act on food waste, reflecting different levels of awareness and concern (Knezevic et al., 2019).

Educational campaigns and targeted policies are effective tools. For example, an information-based strategy in Australia significantly reduced household food waste through practices such as meal planning and better storage (Gimenez et al., 2023). Similarly, managerial attitudes in Swiss-German restaurants emphasize the importance of training staff and implementing preventive measures (Stirnemann & Zizka, 2022).

Cultural factors strongly influence attitudes. In Saudi Arabia, societal values support sustainability, as evidenced by high levels of support for food waste recycling (Alsawah et al., 2022). Conversely, a lack of public awareness in Lithuania highlights the need for improved education and communication strategies (Dagiliūtė & Musteikytė, 2019).

Although awareness of food waste issues is widespread, translating these attitudes into consistent behaviors remains a challenge. Demographic and cultural factors, as well as the effectiveness of educational and policy interventions, play a critical role. Future research and tailored strategies are essential for bridging the gap between awareness and actionable behaviors, thereby contributing to global sustainability.

Reducing food waste has significant economic implications that affect multiple sectors and stakeholders. At the household level, minimizing food waste leads to cost savings, freeing up resources for other priorities such as health and education. Educational campaigns aimed at improving food management practices have been shown to be effective. For example, awareness programs can reduce plate waste by approximately 15% (Pinto et al., 2018). For the food industry, addressing food loss and waste improves operational efficiency and promotes sustainable supply chain practices, although reduced demand for food may pose challenges for producers (Vilariño et al., 2017).

Environmentally, reducing food waste conserves valuable resources such as water, energy and land, and reduces the economic costs associated with greenhouse gas emissions and waste management (Sawaya, 2017). Socially, it strengthens food security by making more food available for consumption, thereby reducing the societal burden of food insecurity (Lipinski, 2020). Policymakers play a critical role by implementing policies such as improved labeling and incentives for food donation, driving a shift toward sustainable practices (Canali et al., 2017).

Globally, reducing food waste is in line with the United Nations Sustainable Development Goals, which aim to halve food waste by 2030. Tailored regional approaches are essential, as cultural and economic differences influence food waste behaviors (Alsawah et al., 2022). Addressing food waste holistically offers economic benefits by increasing resource efficiency, promoting sustainability, and improving food security (Leal Filho & Kovaleva, 2015). The most relevant research and the findings are summarized in Table 1.

Table 1: Authors' main findings related to food waste

Malibari et al. (2023)	Young Saudi women strongly support food reuse, redistribution, and recycling, reflecting high environmental awareness.
Purwanto et al. (2023)	Generation Z in Indonesia demonstrates significant commitment to waste reduction, influenced by their environmental awareness.
McCarthy & Liu (2017)	Despite valuing sustainability, green consumers in Ireland waste food due to spoilage and negligence, revealing a gap between knowledge and action.
Janjic et al. (2019)	Individuals in Serbia who self-report minimal waste discard substantial amounts, indicating discrepancies between self-perception and actual behavior.
Flanagan & Priyadarshini (2021)	Older women in Ireland show greater concern about food waste reduction than younger men, highlighting demographic differences in attitudes.
Knezevic et al. (2019)	Croatian university students show varying levels of knowledge and willingness to act on food waste, reflecting different levels of awareness.
Gimenez et al. (2023)	An Australian educational campaign reduced household food waste by promoting meal planning and better storage practices.
Stirnemann & Zizka (2022)	Swiss-German restaurants emphasize the role of training and preventive measures to reduce food waste.
Alsawah et al. (2022)	Saudi Arabian cultural values strongly support sustainability, evidenced by high public support for food waste recycling initiatives.
Dagiliūtė & Musteikytė (2019)	Lack of public awareness in Lithuania highlights the need for enhanced education and communication strategies to address food waste.
Pinto et al. (2018)	Awareness campaigns reduced plate waste by approximately 15%, demonstrating the effectiveness of targeted educational interventions.
Vilarinho et al. (2017)	Addressing food loss and waste enhances operational efficiency and supply chain sustainability, but may reduce food demand, posing economic challenges for producers.

Sawaya (2017)	Reducing food waste conserves valuable resources like water, energy, and land while lowering greenhouse gas emissions.
Lipinski (2020)	Minimizing food waste improves food security by making more food available for consumption and reducing the economic burden of food insecurity.
Canali et al. (2017)	Policymakers can drive food waste reduction through strategies like improved labeling and food donation incentives, fostering sustainable practices.
Leal Filho & Kovaleva (2015)	Reducing food waste aligns with the UN Sustainable Development Goals, contributing to global sustainability through improved resource efficiency, food security, and waste management.

METHODOLOGY

After reviewing the relevant national and international literature, the authors set the following research questions related to consumer attitudes based on food waste reduction intention and sustainable food consumption practices:

RQ1: Which groups of consumers can be distinguished on the basis of their attitudes towards food waste?

Sustainable food consumption practices:

RQ2: How do Hungarian consumers engage in sustainable practices, and what motivates them to adopt these behaviors?

The questionnaire was typically based on closed questions, namely metric and non-metric scales. Awareness of food purchasing was measured using five-point Likert scales with endpoints 1: Not at all typical and 5: Completely typical. Food waste reduction intentions (FWRI) were developed by Habib et al. (2023) and included the following items:

FWRI_1. In the near future, I intend to encourage colleagues and friends to reduce household food waste.

FWRI_2. I plan to take part in activities related to recycling household food waste

FWRI_3. I will take part in household food waste recycling activities advocated in social media in the near future.

FWRI_4. I plan to promote the recycling of household food waste to my friends, family, and peers.

FWRI_5. I will encourage my friends, colleagues, and family to reduce household food waste.

The frequency of food disposal was measured using a frequency scale, capturing how often respondents discard specific food items like canned

goods, leftovers, and dairy products. Emotional reactions to food waste were evaluated by asking participants to report their feelings, such as guilt, regret, or anger, on a scale of intensity. Motivations for avoiding food waste were assessed through an open-ended question and categorized into financial, emotional, awareness-based, and social/environmental factors. The recycling practices of the respondents were evaluated using a descriptive scale based on the respondents' reported behaviors, including repurposing, composting, and feeding animals. The demographic information of the participants was measured using categorical scales in order to create distinct groups. The demographic information in question includes gender, age, education, and financial situation.

The primary research was based on quantitative methodology. In December 2023, the researchers conducted an online questionnaire survey among Hungarians. The questionnaire was distributed on the social media channel Facebook, therefore the sampling technique was convenience sampling. In the end, 231 people were reached in the sample.

The questionnaire utilized in the study was comprised of several essential elements. The questionnaire included questions designed to assess the participants' intentions to reduce food waste, adapted from the instrument developed by Habib et al. (2023) to evaluate the motivation to minimize food waste. Another section of the questionnaire focused on the categorization of food waste according to product type, employing an ordinal scale to quantify the frequency of waste across a range of food categories. Additional questions were posed to ascertain the waste management practices and reasons for waste generation, which were then subjected to thematic analysis in order to identify any recurring patterns. In addition, the questionnaire gathered information regarding the socio-demographic characteristics of the respondents, with a view to identifying any potential correlations between demographic factors and food waste behaviors.

The data obtained from Google Forms were initially imported into Excel for analysis. Following the cleansing of the data, the analyses were conducted using the mathematical-statistical software package SPSS 26. Multivariate statistical analyses were employed to characterize each consumer group and to map the attitudes regarding food waste. A cross-tabulation analysis was employed to examine the existing relationships.

RESULTS

The online survey mainly reached women, young people and graduates with average or above average income (Table 2).

Table 2: Demographic composition of the sample

Gender	68.4% female	31.6% male		
Age	57.1% 18-29 y	16.0% 30-45 y	24.2% 46-64 y	2.6% 65+ y
Education	1.3% vocational certificate	77.5% secondary education (<i>Matura</i> – high school graduation)	24.2% higher education	
Residence	1.3% village	77.5% small town	21.2% city	
Financial situation	24.0% BTA*	41.0% average	35.0% ATA*	
Change in financial situation in 1 year	36.8% worsened	44.6% no change	32.5% improved	

Source: Own research, n=231; Note * Below the Average ** Above the Average

As a first step in the research, the respondents were divided into two groups by summing the scores on the five statements of attitude towards food waste reduction intention, and then examining the position and shape indicators. The mean of attitude amounted to 13.77, its mode and median were 14, i.e. the responses follow a normal distribution. Respondents with a score below 14 were labelled as careless people, representing 61% of the sample, while those with a score above 15 were labelled as conscious people, representing 39% of the sample. Careless people who refuse to participate in initiatives to reduce household food waste may reflect a disconnect from or disregard for environmental stewardship. On the other hand, conscientious people who demonstrate a strong commitment to reducing household food waste and actively participate in efforts to promote recycling and sustainability make a meaningful impact on reducing food waste in their communities.

Adjusted standardized residuals (>2) show that the careless tend to be young and of average income, while the conscious are middle-aged or older and have above-average financial resources (Table 3). These results contradict the findings of Szűcs (2019), who found that awareness decreases as income levels increase.

Table 3: Correlations between consumer groups and demographic variables

Demographic variables		Careless	Conscious	χ^2 ; p; Cramer's V	Corr. stand. residual*		Typical cluster
					Careless	Conscious	
	15-29	66.7 %	42.2 %	13.469	3.7	-3.7	careless
Age	30-45	12.1 %	22.2 %	0.004	-2.1	2.1	conscious
	46-64	19.1 %	32.2 %	0.241	-2.3	2.3	conscious
	BTA	18.4 %	10.0 %	14.043	1.7	-1.7	none
Financial situation	average	58.2 %	43.3 %	0.001	2.2	-2.2	careless
	ATA	23.4 %	46.7 %	0.247	-3.7	3.7	conscious

Source: Own research, n=231; Note: corrected standardized residual

The results of the survey indicate that there are notable differences in the frequency of food disposal across various product categories among Hungarian consumers. Canned foods were the least likely to be discarded, with 80.1% of respondents indicating that they never dispose of them. In contrast, dairy products and bakery items exhibit higher rates of disposal, with 10.8% and 15.6% of participants indicating that they often discard these items, respectively. Leftovers and fruits and vegetables show moderate levels of waste, with 11.3% and 5.6% of respondents reporting a tendency to discard these items with some regularity. Furthermore, the data indicates that individuals who are less mindful of their consumption habits are more likely to discard bakery items (19.1%) than those who are more deliberate in their actions (10.0%). This underscores the influence of consumer awareness on waste behavior. In general, perishable categories such as dairy and bakery products are more susceptible to waste, emphasizing the necessity for targeted strategies to reduce food waste in these areas (Table 4).

Table 4: The frequency of food disposal by product category

		Never	Rarely	Often
Canned food	Total	80.1%	17.7%	2.2%
	Conscious	77.8%	20.0%	2.2%
	Careless	81.6%	16.3%	2.1%
Leftover	Total	37.2%	51.5%	11.3%
	Conscious	37.8%	55.6%	6.7%
	Careless	36.9%	48.9%	14.2%
Fruit, vegetables	Total	44.6%	49.8%	5.6%
	Conscious	46.7%	46.7%	6.7%
	Careless	43.3%	51.8%	5.0%
Bakery	Total	39.4%	45.0%	15.6%
	Conscious	45.6%	44.4%	10.0%
	Careless	35.5%	45.4%	19.1%
Dairy products	Total	31.2%	58.0%	10.8%
	Conscious	31.1%	58.9%	10.0%
	Careless	31.2%	57.4%	11.3%

A total of 100 individuals, representing 42.5% of the 231 respondents, identified reasons for discarding food. Additionally, a relatively high proportion of respondents identified food waste as a consequence of expired shelf life or the unnecessary purchase and preparation of food. Twenty-nine respondents indicated that they do not discard food at all. The data further indicate that only a limited number of items are discarded due to perceived poor quality, with only five respondents – representing less than three percent of the total sample – reporting this as a reason. Even when we include the 13 respondents who discard food because they perceive it to no longer be fresh, only 7.5 percent of participants cited subjective reasons, such as considering the purchased items to be of poor quality, as a cause for food waste (Figure 1).

Figure 1: Reasons of food waste



Source: Quantitative research, n=100

One of the open-ended questions in the survey addresses the emotions that consumers experience when they waste food. Nearly half of the respondents (111 people) indicated that throwing away food evokes negative feelings. The majority of responses reflected a generally negative attitude, which indicates that respondents are reluctant to throw away purchased food. Feelings of regret, anger, guilt, and even remorse (14 respondents) are common when food is thrown away (Figure 2). Only 10 respondents reported that throwing away food does not evoke an emotional response. Notably, 7 respondents indicated that they do not waste food at all.

Figure 2: Feelings in regard to food waste



Source: Quantitative research, n=111

The objective of the open-ended question was to ascertain the factors that motivate respondents to avoid food waste. As anticipated, the largest group of respondents (73 individuals) identified financial concerns, particularly the perceived loss of money, as their primary motivation. It is also noteworthy that a considerable number of respondents (55 individuals) identified negative emotional responses associated with food waste as a significant factor influencing their decision to reduce waste. Additional motivators included awareness and education, though fewer respondents emphasized social or environmental factors. Specifically, only 27 respondents indicated awareness of global hunger, and just 18 acknowledged the labor and energy involved in food production. These findings indicate that financial considerations are the primary factor influencing the respondents' efforts to minimize food waste (Figure 3).

Figure 3: Motivations for avoiding food waste



Source: Quantitative research, n=173

The objective of this inquiry was to ascertain the methods by which respondents repurpose food items that would otherwise be discarded. The majority of respondents indicated that they engage in some form of food recycling. The respondents' approaches varied significantly. For example, some respondents reported converting dry bread into French toast or breadcrumbs, using withered fruit like apples to prepare apple pie, or blending older fruits. The second most common method, as indicated by 57 respondents, was the feeding of pets. One particularly noteworthy response was as follows: "I provide sustenance to the ducks, and then I consume the ducks". It is noteworthy that 17.1% of respondents indicated that they do not engage in food recycling, which suggests that the majority of this food is likely discarded. Furthermore,

respondents indicated that composting and freezing are common practices, while four respondents reported that they donate surplus food to those in need.

CONCLUSION

Hungarian consumers can be categorized into two primary groups based on their attitudes towards food waste: the first group, the “careless”, consists of younger, average-income individuals, while the second group, the “conscious”, consists of older, above-average-income individuals. This study underscores the necessity for targeted interventions, particularly for the younger, average-income demographic, which exhibits a lower propensity for engaging in food waste reduction. Educational campaigns should prioritize cost-saving strategies and evoke emotions such as guilt or regret to facilitate behavior modification. Innovations in packaging, extending shelf life, and introduction of community programs incentivizing recycling or food donation could further reduce waste.

The theoretical implications challenge previous consumer behavior research by showing how demographic and attitudinal differences influence food waste, emphasizing the role of financial and emotional motivators in promoting sustainable consumption. The study also underscores the importance of perishability, suggesting that theoretical frameworks should address product-specific challenges in various cultural contexts. This study provides valuable insights into Hungarian consumer attitudes and behaviors regarding food waste. The identification of products most prone to waste, such as milk, bread, and cooked food, assists stakeholders in the development of waste reduction initiatives. Emotions like regret and financial loss emerge as key motivators for change, underscoring the importance of sustainable practices such as recycling and repurposing. These insights can guide industry, government, and NGOs in the promotion of meal planning and circular economy practices, contributing to national strategies for reducing food waste and fostering sustainability.

It should be noted that the study is not without limitations. The relatively modest sample size and reliance on self-reported data may introduce bias and restrict the generalizability of the findings to the broader Hungarian population. Furthermore, the study primarily concentrates on consumer attitudes and behaviors, without fully investigating external factors such as supply chain dynamics, cultural influences, or infrastructure constraints.

Future research could address these limitations by expanding the sample size and employing mixed methods to gain a deeper understanding of food

waste behaviors. Comparative studies across different regions or countries could provide a broader context, while longitudinal research could track changes in consumer attitudes and practices over time. Further investigation of external factors, such as marketing strategies or food donation systems, could also facilitate the development of comprehensive strategies to effectively reduce food waste.

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**DIGITAL ECONOMY
and ARTIFICIAL INTELLIGENCE**

MACHINE LEARNING PREDICTION OF PRECIOUS METALS: COMPARATIVE ANALYSIS OF LSTM, GBM, FBM, AND BB MODELS

Busra AGAN*

This study provides a comprehensive comparative analysis of advanced forecasting models for predicting the prices of gold, silver, platinum, and palladium by applying Long Short-Term Memory (LSTM), Geometric Brownian Motion (GBM), Fractional Brownian Motion (FBM), and Brownian Bridge (BB). Using metrics like MAPE, RMSE, and the Hurst Exponent, the results show that the Hurst exponent is above 0.5 in all commodities and in each period. The findings also indicate that gold and silver exhibit persistent trends, with LSTM outperforming other models for silver in volatile periods. GBM is effective for long-term predictions for gold, while LSTM and BB excel in forecasting palladium. GBM, BB, and LSTM capture volatility and market randomness well for platinum. The study offers valuable insights into selecting the best forecasting model based on the market conditions. Therefore, this study provides critical insights into the effectiveness of machine learning and stochastic methods in forecasting precious metal prices under different macroeconomic conditions, offering valuable implications for policymakers and market participants in managing energy price risks and uncertainty. The findings underscore the importance of combining machine learning approaches with stochastic models in order to achieve robust and accurate predictions in the highly dynamic and uncertain metals market.

Keywords: *precious metal commodity price, commodity markets, Long Short-Term Memory, Geometric Brownian Motion, Fractional Brownian Motion, Brownian Bridge*

JEL classification: *Q02, E32, C53*

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INTRODUCTION

Precious metals such as gold, silver, platinum, and palladium have long been considered safe-haven assets and vital components of global financial markets. Their prices are influenced by a complex interplay of factors, including geopolitical tensions, macroeconomic fluctuations, and market dynamics. More importantly, various studies (Abid et al., 2023; Farid et al., 2021; Rehman et al., 2018; Rehman and Vinh Vo, 2020; Rehman and Vo, 2021; Sifat et al., 2021) conclude that the LSTM model outperforms traditional statistical methods, such as Autoregressive Integrated Moving Average (ARIMA) and Generalized Autoregressive Conditional Heteroskedasticity (GARCH), in forecasting agricultural commodity prices. Accurately predicting the prices of precious metals such as gold, silver, platinum, and palladium is of critical importance due to their inherent volatility and the numerous factors influencing their value (Bakas and Triantafyllou, 2020; Mokni et al., 2021; Uddin et al., 2019). These include macroeconomic indicators like interest rates, inflation, and currency exchange rates; market sentiment shaped by investor behavior, geopolitical tensions, and global economic outlook; and supply-demand dynamics, including mining production, industrial demand, and recycling rates.

Precious metals such as gold, silver, platinum, and palladium have long been recognized as reliable hedges and safe-haven assets, particularly during periods of economic turmoil. On the other hand, these metals have consistently played a pivotal role as a hedge against inflation and a financial safe haven during periods of economic turmoil and geopolitical uncertainty. Their unique properties make them a reliable store of value, especially in times of market volatility and recession when other asset classes falter. During such times, investors and policymakers turn to precious metals as a last resort, reinforcing their importance in stabilizing financial portfolios and safeguarding economic stability. Understanding the dynamics of these markets is crucial not only for effective risk management, but also for developing strategies to navigate the complexities of global financial systems. This relevance underscores the need for advanced and accurate forecasting models that can capture the multifaceted drivers of precious metal prices.

In recent years, machine learning techniques have emerged as powerful tools for addressing the limitations of conventional forecasting models. Among these, Long Short-Term Memory (LSTM) networks, a type of recurrent neural network, have demonstrated superior performance in capturing non-linear patterns and long-term dependencies in time series data. These networks leverage memory cells to store and update information over time, enabling them to rec-

ognize trends and seasonality in complex datasets. Alongside LSTM, stochastic models such as Geometric Brownian Motion (GBM), Fractional Brownian Motion (FBM), and Brownian Bridge (BB) continue to be widely used due to their simplicity and ability to model random processes in financial markets. GBM assumes a constant percentage growth rate with randomness, FBM incorporates long-term dependencies through Hurst exponent adjustments, and BB models price paths between fixed points, making them particularly useful in specific scenarios. There are several studies (Patil et al., 2023; Pandit et al., 2024; Paul et al., 2022; Rana et al., 2024) that apply ML techniques for the prediction of commodity prices so as to choose the best alternative model.

LSTM networks have become increasingly popular due to their ability to capture long-term dependencies in sequential data. Sherstinsky (2018) highlights the core principles of recurrent neural networks (RNNs) and LSTM architectures, underlining their significance in time-series forecasting, particularly for agricultural price predictions. Similarly, Zhang et al. (2018) developed an LSTM-based model tailored for forecasting water table depth, showcasing the model's adaptability in addressing agriculture-related metrics. The study by Lindemann et al. (2021) further emphasizes the effectiveness of LSTM in time-series forecasting, demonstrating its reliability across diverse environmental variables. Furthermore, the incorporation of attention mechanisms in LSTM networks, as examined by Zhou et al. (2016) and Qiu et al. (2020), enhances model performance by enabling it to focus on critical parts of the input data.

The volatile nature of precious metal markets, driven by factors such as macroeconomic fluctuations and geopolitical events, poses significant challenges for accurate price prediction. Traditional econometric models often fall short in capturing the non-linear and dynamic behavior of these markets, highlighting the need for more sophisticated approaches. Recent advancements in machine learning techniques, such as LSTM networks and stochastic models, including GBM, FBM, and BB, have shown promise in addressing these complexities. Accurate price forecasting is crucial for stakeholders like investors, industries and policymakers, making it imperative to identify the most effective models for this purpose. While existing literature provides valuable insights, there is a notable gap in studies that systematically compare advanced machine learning models with stochastic methods for long-term price prediction of precious metals. This study addresses this gap by conducting a comprehensive comparative analysis of LSTM and three stochastic models so as to evaluate their effectiveness in forecasting the prices of gold, silver, platinum and palladium during various macroeconomic periods.

This study aims to conduct a comprehensive comparative analysis of LSTM, GBM, FBM, and BB models in forecasting the prices of precious metals across various significant financial and geopolitical periods. By evaluating the performance of these models using key metrics such as Mean Absolute Percentage Error (MAPE) and Root Mean Square Error (RMSE), the research seeks to identify the most effective approaches for predicting the volatile price movements of gold, silver, platinum, and palladium. Additionally, the study incorporates the Hurst exponent to assess the long-term memory and persistence characteristics of these metals, providing deeper insights into their price dynamics. The findings of this study conclude that precious metals with higher Hurst exponents exhibit stronger long-term trends and are better predicted by memory-driven models like FBM. LSTM consistently achieves lower MAPE and RMSE, making it the most reliable model for long-term forecasting.

The findings of this study contribute to the growing body of literature on machine learning applications in financial markets and offer practical implications for stakeholders seeking to enhance their forecasting capabilities in the precious metals sector. This study not only advances the literature, but also provides actionable insights for market participants navigating the highly dynamic and uncertain precious metals market. By comparing advanced machine learning models with traditional stochastic methods, the study underscores the importance of selecting appropriate forecasting techniques tailored to the unique characteristics of financial time series data. This study continues by presenting a methodology and data description in Section 2. Section 3 outlines the empirical findings and subsequent discussion. Finally, Section 4 provides a summary of the conclusions drawn from the study.

METHODOLOGY AND DATA

METHODOLOGY

GEOMETRIC BROWNIAN MOTION

Geometric Brownian Motion (GBM) is a stochastic process widely used to model the dynamics of financial asset prices over time. The price of an asset, $S(t)$, is defined by the following differential equation:

$$dS(t) = S(t)dt + \sigma S(t)dW(t) \quad (1)$$

In Equation 1, $S(t)$ is the asset price at time t , μ is the expected rate of return (drift), σ is the volatility of the asset, and $W(t)$ is the standard Brownian motion. Based on Algorithm 1, each price path is calculated by equation 2.

$$S(t + \Delta t) = S(t) \exp \left(\left(\mu - \frac{\sigma^2}{2} \right) \Delta t + \sigma \sqrt{\Delta t} Z_t \right) \quad (2)$$

In Equation 2, Δt denotes the time step and $Z_t : N(0,1)$ denotes the normal distribution. After simulating n Brownian motions, the average price path $AGBM(t)$ at each time step t can be calculated by Equation 3.

$$AGBM(t) = \frac{1}{n} \sum_{i=1}^n S_i(t) \quad (3)$$

This equation gives the average value at each time step over n simulation paths.

FRACTIONAL BROWNIAN MOTION

Fractional Brownian Motion (FBM) is a generalization of the standard Brownian motion and is characterized by the Hurst parameter H . The Hurst parameter takes a value between $0 < H < 1$. This parameter controls the dependence in the process. When $H=0.5$, FBM is equivalent to the standard Brownian motion. $H>0.5$ means long-term positive dependence and $H<0.5$ means long-term negative dependence. The FBM process is modeled as in equation 4:

$$B_H(t) = \int_0^t (t-s)^{H-\frac{1}{2}} dW(s) \quad (4)$$

where, $B_H(t)$ is the fractional Brownian motion defined by the Hurst parameter H and $dW(s)$ is the differential of the standard Brownian motion. Based on Algorithm 2, each price path is calculated by equation 5.

$$FBMPaths_i(t) = S_0 + \sum_{j=1}^t N(0, \sqrt{dt}) \text{Cholesky}(CovMatrix) \quad (5)$$

If multiple FBM simulations are performed, the average price path at each time step t can be calculated by equation 6:

$$AFBM(t) = \frac{1}{n} \sum_{i=1}^n FBMPaths_i(t) \quad (6)$$

This equation gives the average value at each time step over n simulation paths.

BROWNIAN BRIDGE

A Brownian Bridge is a version of the standard Brownian motion with specific starting and ending points. In the Brownian Bridge process, the value of the Brownian motion expressed as $B(t)$ at time $t = T$ is constrained by $B(T)$. The Brownian Bridge can be modeled as follows:

$$B(t) = W(t) - \frac{t}{T} W(T) \quad (7)$$

In Equation 7, $B(t)$ is the BB at time t , $W(t)$ is the standard Brownian motion at time t , and T is the final time point. This equation ensures that the process $B(t)$ returns to zero at time $t=T$. Since $W(t)$ is the standard Brownian motion, $W(t)$ is considered as a normally distributed random variable. In Algorithm 3, dt is defined as the time step and the total number of steps for each simulation is $N=T/dt+1$. To simulate Brownian motion at each time step t during time period t , the normal distribution $N(0, \sqrt{dt})$ is used. Based on Algorithm 3, each price path is calculated by equation 8.

$$BridgePaths_i(t) = S_0 + \sum_{j=1}^t N(0, \sqrt{dt}) - \frac{t}{T} \sum_{j=1}^T N(0, \sqrt{dt}) \quad (8)$$

This formula calculates the value of the Brownian Bridge at each time step t for the I -th simulation. After performing n Brownian Bridge simulations, the average price path $ABB(t)$ at each time step t can be calculated by equation 9.

$$ABB(t) = \frac{1}{n} \sum_{i=1}^n BridgePaths_i(t) \quad (9)$$

This equation gives the average value at each time step over n simulation paths.

LONG SHORT-TERM MEMORY (LSTM)

Long Short-Term Memory (LSTM) networks, a specialized type of Recurrent Neural Network (RNN), are designed to identify and model long-term de-

dependencies in sequential data, making them particularly effective for forecasting tasks involving time series data. Unlike traditional RNNs, LSTMs address the vanishing gradient problem through their unique architecture, which comprises cell states and gated mechanisms. These components enable LSTMs to retain and update information over time, making them ideal for capturing complex, non-linear patterns in data.

The cell state, often referred to as the “memory,” serves as a conveyor belt that runs through the entire sequence. It retains relevant information and prevents short-term memory effects, thereby ensuring the network can maintain context over longer time intervals. The process of passing information through these gates enables LSTMs to selectively filter and prioritize data, which is critical for handling sequences with both short- and long-term dependencies.

This sophisticated architecture, combined with LSTM’s ability to handle variable-length sequences, has led to its widespread adoption across various domains, including finance and commodity price forecasting. For readers interested in further exploring LSTM’s functionality and applications, foundational works such as Sherstinsky (2018) and advanced implementations with attention mechanisms as discussed by Zhang et al. (2018) offer valuable insights.

The cell state is updated via the input gate. The sigmoid function receives input from the previously hidden state and the current input, adjusting the value between 0 and 1 to determine what needs to be updated.

$$i_t = \sigma(\omega_i \ h_{t-1}, x_t + b_i) \quad (10)$$

The LSTM uses the forgetting gate to assist it in choosing which data to discard.

$$f_t = \sigma(\omega_f \ h_{t-1}, x_t + b_f) \quad (11)$$

Computing the cell state is the next step. Initially, the forgetting vector is multiplied by the cell state of the preceding layer. The information must be kept in the new cell state if it is multiplied by a value that is near to 1.

EVALUATION METRICS

The performance of the model was assessed in this study using two distinct evaluation metrics: mean absolute percentage error (MAPE) and root

mean square error (RMSE). The difference between the actual value and the expected value is measured by RMSE. The following is the definition:

$$\text{RMSE} = \sqrt{\frac{1}{n} \sum_{i=1}^n (y_i - \hat{y}_i)^2} \tag{12}$$

The difference between the actual and anticipated values is expressed as a percentage using the MAPE metric, which is frequently used in time series prediction. The following is the definition of MAPE:

$$\text{MAPE} = \frac{1}{n} \sum_{i=1}^n \left| \frac{y_i - \hat{y}_i}{y_i} \right| 100 \tag{13}$$

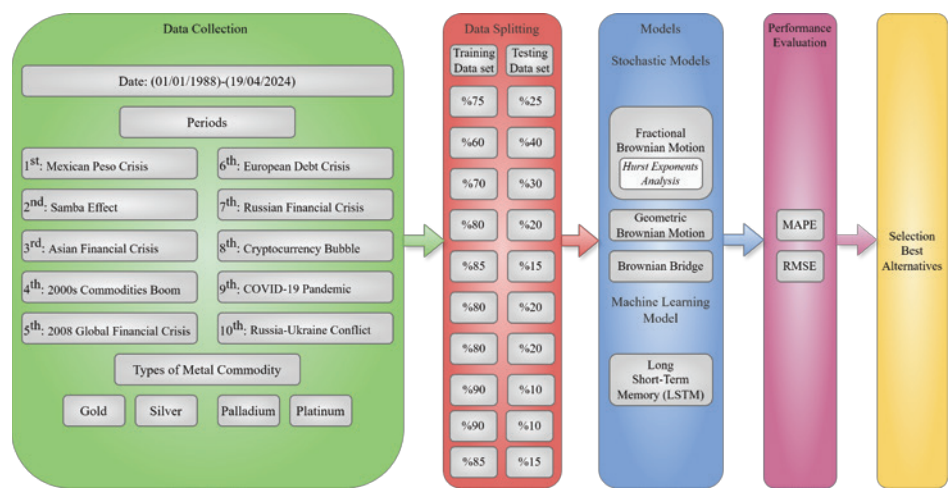
The variables n and $\hat{y}_i$ represent the number of data samples and the real and derived values of the i -th sample data, respectively, in Equations (10) and (11).

Table 1. MAPE judgment accuracy of the forecasting method

Judgment of Accuracy	MAPE
Highly accurate	MAPE < 10%
Good accuracy	10% ≤ MAPE < 20%
Reasonable	20% ≤ MAPE < 50%
Inaccurate	MAPE ≥ 50%

Table 1 summarizes the ruling on any forecasting technique utilizing MAPE by Lawrence et al. (2009). RMSE is calculated by deducting each data sample's actual value from its anticipated value. The root operation is then carried out after calculating the average of the square values. To calculate MAPE, divide the value that results from deducting each sample's real value from its anticipated value by the real value once more. In short, the methodological framework is presented in a flow chart in Figure 1.

Figure 1. The flow chart diagram process



Source: Author's compilation

DATA AND DESCRIPTION

In this study, we forecast the prices of one of the commodity classes, which is precious metal commodities, by applying machine learning (ML) techniques and stochastic models. By utilizing these advanced forecasting techniques, the study aimed to provide a comprehensive understanding of price fluctuations during key historical periods marked by economic and political issues. The chosen methods allowed for capturing both stochastic and non-linear patterns in the data, offering a robust framework for predicting future trends in precious metals. First, a brief explanation of the data kinds and origins that were considered is provided. This data is obtained for analysis in this study on the daily spots and futures prices of four precious commodities. Table 2 reports summary information on commodity data.

Table 2. Data Information

Commodity	Symbol	Underlying Spot Commodity	Source
Gold	GLD	Gold Bullion London Bullion Market United States Dollar Per Metric Tonne Ounce Delay	ICE Benchmark Administration Ltd.
Silver	SLV	Silver, Handy and Harman (New York) USD / Troy Ounce	Handy and Harman
Platinum	PLT	London Platinum Free Market United States Dollar Per Troy Ounce	London Metal Exchange
Palladium	PLD	Palladium U\$/Troy Ounce	London Metal Exchange

The analysis explores the impact of key economic crises and global events on financial and commodity markets over the years. Beginning with the Mexican Peso Crisis (Tequila Effect) (1994-12-20 to 1995-12-31) (Sachs et al. 1996), this period reflects a sharp depreciation of the Mexican peso, resulting from unsustainable fiscal deficits and capital flight. The crisis caused a ripple effect in Latin America, destabilizing regional financial markets. Next, the Samba Effect (1996-01-01 to 1997-12-31) (Giambiagi and Ronci, 2004) highlights Brazil's struggle with high inflation and public debt, leading to devaluation fears and significant financial stress in emerging markets. The Asian Financial Crisis (1997-07-02 to 1999-12-31) (Krugman, 1998) marked a severe economic downturn in East Asia, triggered by speculative attacks on currencies. This event led to a dramatic reduction in investor confidence, massive capital outflows, and energy price volatility. Following this, the 2000s Commodities Boom (2000-01-01 to 2008-02-28) (Hamilton, 2009) underscores a period of sustained price increases in energy and raw materials, driven by robust demand from rapidly growing economies such as China and India.

The Global Financial Crisis (2008-03-01 to 2010-12-31) (Brunnermeier, 2009) remains one of the most profound economic disruptions, originating from the collapse of the U.S. housing market and spreading globally. This period saw steep declines in commodity prices as demand plummeted amidst a global recession. Concurrently, the European Debt Crisis (2010-02-01 to 2012-12-31) (Lane, 2012) emerged, exacerbated by unsustainable sovereign debts in countries like Greece and Spain, further dampening economic recovery efforts and causing fluctuations in commodity prices. The Russian Financial Crisis (2013-01-01 to 2016-12-31) (Gurvich and Prilepskiy, 2015) followed, characterized by falling oil prices, Western sanctions, and a plunging ruble. The subsequent Cryptocurrency Bubble (2017-01-07 to 2020-01-01) (Cheah

and Fry, 2015) was marked by dramatic surges and crashes in digital currency valuations, reflecting speculative investment behaviors and raising questions about their impact on broader financial markets.

The COVID-19 Pandemic (2020-03-11 to 2022-12-30) (Baldwin and Weder, 2020) brought unprecedented global disruption, with lockdowns reducing energy demand and causing extreme volatility in commodity prices. Lastly, the Geopolitical Crises and Commodity Price Movements during the Russia-Ukraine Conflict (2022-02-24 to present) (Khurshid et al., 2023) have significantly influenced global energy markets. The conflict has led to supply chain disruptions, particularly in Europe, and heightened price instability, showcasing the intricate link between geopolitical tensions and commodity markets.

EMPIRICAL FINDINGS

This study primarily focuses on exploring the performance of advanced models, including GBM, FBM, BB and LSTM, during periods of significant financial and geopolitical crises. These events are characterized by non-linear patterns, abrupt changes, and varying levels of volatility, which traditional models like ARIMA may struggle to capture effectively. Consequently, this study prioritizes models designed to handle such complexities and long-term dependencies. Therefore, advanced models such as GBM, FBM, BB and LSTM are employed to evaluate the forecasting performance of precious metal prices during financial and geopolitical crises. Linear models like ARIMA often struggle to capture the nonlinear dynamics, sudden shifts, and long-term memory effects commonly observed in financial markets. Unlike many traditional forecasting studies, our analysis includes the Hurst exponent to assess the persistence and memory in time series data during different crisis periods. This focus on long-term memory inherently aligns with advanced models like LSTM and stochastic processes, making them more suitable for this study's objectives.

HURST EXPONENTS ANALYSIS

The determination of the Hurst exponent is usually done using techniques such as the Rescaled Range (R/S) approach, Variance-Time approach, or the detrended fluctuation analysis (DFA). In this paper, the Hurst exponent is estimated using R/S analysis, which is particularly appropriate for analyzing

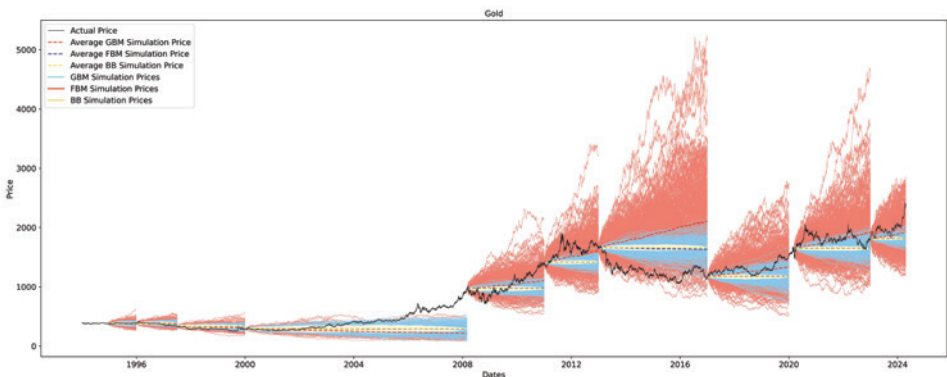
financial time series. The calculated Hurst exponents determined the trends with respect to major market events.

GBM, FBM, BB AND LSTM ANALYSIS

After analyzing the Hurst exponent, which is a critical parameter in FBM analysis, GBM, FBM, BB and LSTM analyses are examined. FBM is a generalization of the standard Brownian Motion that allows for long-term dependence on data. Beginning on January 1, 1988, and ending on April 19, 2024, we collected worldwide index data for gold, silver, palladium and platinum. We used the training set to determine the parameters needed for the simulation after dividing the data into training and test sets with different proportions for each period.

The price simulation results for gold in Figure 2 show the predicted prices of gold over ten periods using three stochastic models: GBM, FBM and BB. The average simulated prices from GBM, FBM and BB are represented by the blue, red and yellow lines, respectively, while the actual price data is displayed in black. All of these methods are run with 500 simulation repetitions. The forecast results suggest that gold price dynamics are influenced by both short-term stochastic behaviors and long-term memory effects. Each model provides varying levels of accuracy depending on the specific characteristics of each period, with GBM and FBM being more suitable for persistent or volatile trends, while BB is better suited for stable or less complex scenarios. The average of stochastic models is shown in Figure 3.

Figure 2. Forecasting results using GBM, FBM and BB processes for ten periods (gold)



Following this, a comparison of the models of gold price simulations in Figure 3 shows the predicted prices of gold over eight periods using three stochastic models: LSTM, GBM, FBM, and BB for ten periods. For each period, these models are compared and showed the best model selection. GBM (Geometric Brownian Motion) performs well in most periods, indicating its superiority in capturing non-linear patterns and long-term dependencies.

Figure 3. Comparison of LSTM, GBM, FBM and BB methods for ten periods (gold)



Figure 4 presents the forecasting of silver price across ten periods using GBM, FBM and BB models. Each model provides unique insights into price dynamics, with GBM reflecting average market trends, FBM incorporating long-term correlations, and BB modeling convergence toward specific values, collectively demonstrating the immediate and long-term impacts of these crises on silver prices.

Figure 4. Forecasting results using GBM, FBM and BB processes for ten periods (silver)

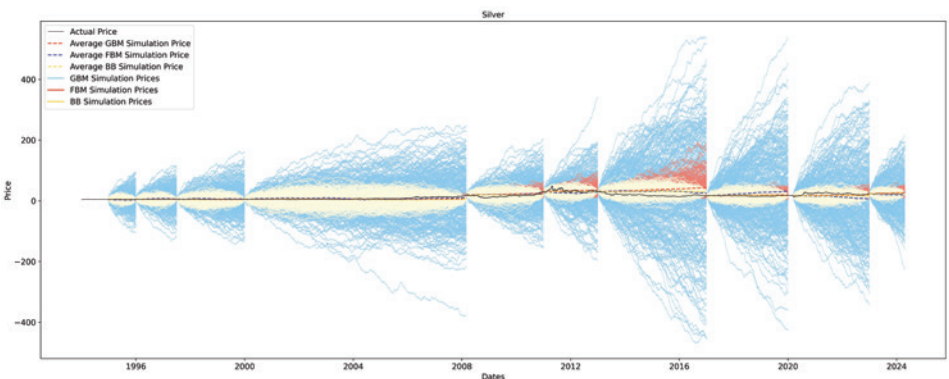
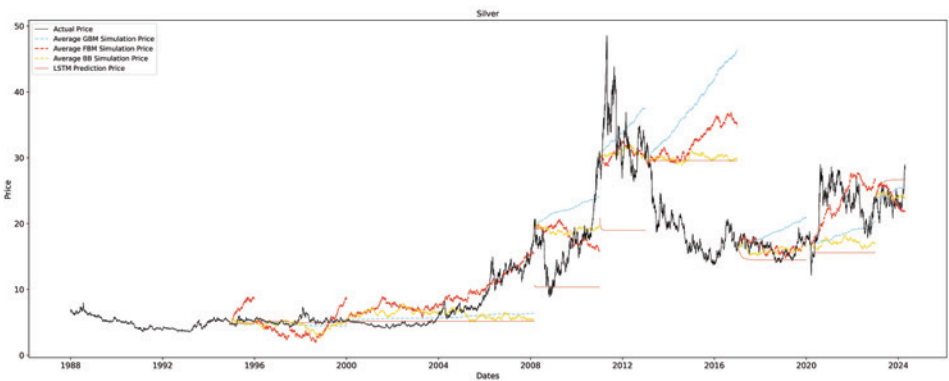


Figure 5 shows the comparison of Long Short-Term Memory and average of stochastic models for ten periods. LSTM is the best model for silver's volatile and complex periods, where non-linear relationships and market dynamics are more critical.

Figure 5. Comparison of LSTM, GBM, FBM and BB methods for ten periods (silver)



The price simulation results of palladium presented in Figure 6 show the predicted prices of palladium over ten periods using three stochastic models: GBM, FBM and BB. These periods include the Global Financial Crisis (2008-2010), with sharp fluctuations and significant price corrections; the European Debt Crisis (2010-2012), characterized by moderate price instability; the Russian Financial Crisis (2013-2016), influenced by Russia's major role in palladium supply and geopolitical tensions; the Cryptocurrency Bubble (2017-2020), where speculative financial trends contributed to price volatility; the COVID-19 Pandemic (2020-2022), resulting in extreme price uncertainty due to supply chain disruptions and fluctuating demand. Each model captures distinct dynamics, with GBM reflecting average price trends, FBM incorporating long-term dependencies, and BB focusing on reversion patterns, collectively demonstrating palladium's susceptibility to macroeconomic and geopolitical events.

Figure 6. Forecasting results using GBM, FBM and BB processes for ten periods (palladium)

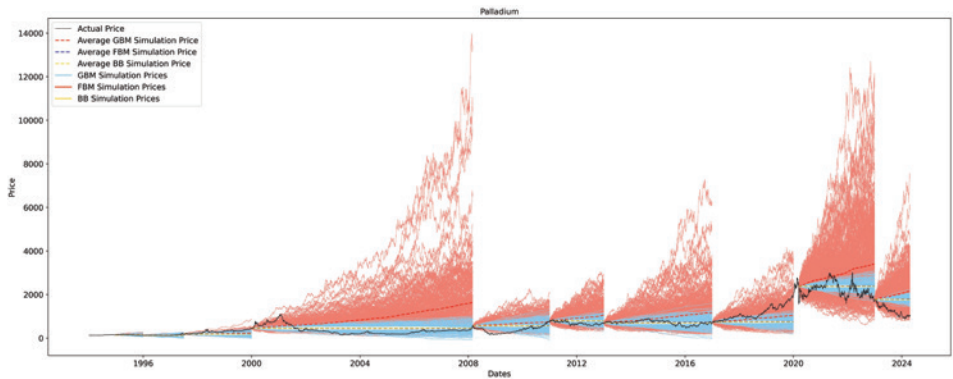
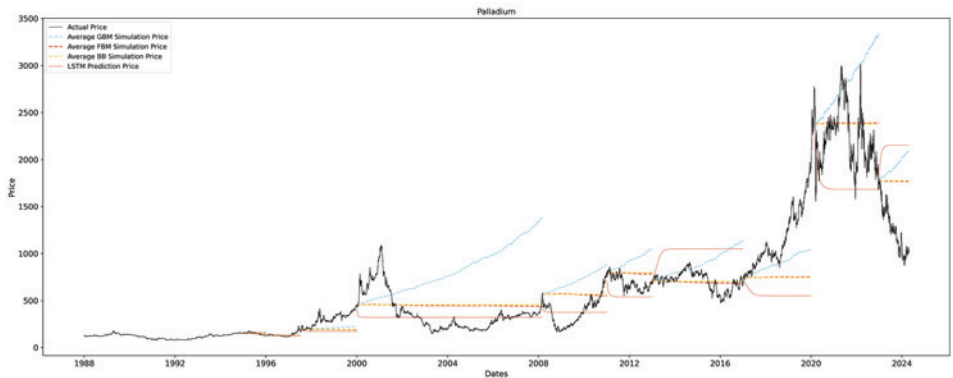


Figure 7 shows the comparison of LSTM and the average of stochastic models for ten periods. LSTM and BB dominate in terms of accuracy across almost all periods, indicating their ability to adapt to long-term trends and short-term volatility.

Figure 7. Comparison of LSTM, GBM, FBM and BB methods for ten periods (palladium)



The price simulation results for platinum presented in Figure 8 show the predicted prices of platinum over ten periods using three stochastic models: GBM, FBM and BB. These periods include the Asian Financial Crisis (1997-1999), where platinum prices reflected global market instability; the 2000s Commodities Boom (2000-2008), characterized by significant price growth

fueled by increasing industrial demand; the 2008 Global Financial Crisis (2008-2010), marked by extreme volatility and sharp price declines; the Russian Financial Crisis (2013-2016), heavily influenced by geopolitical events and Russia’s role in global platinum supply; the COVID-19 Pandemic (2020-2022), showing extreme price volatility due to disrupted supply chains and fluctuating demand.

Figure 8. Forecasting results using GBM, FBM and BB processes for ten periods (platinum)

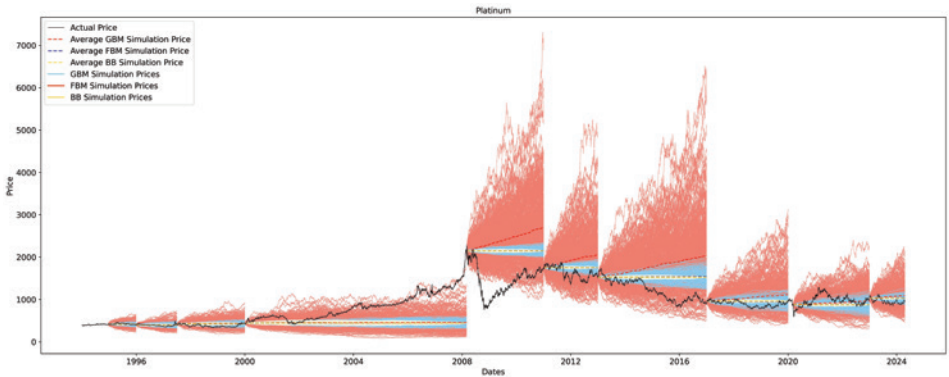


Figure 9 shows the comparison of LSTM and the average of stochastic models for ten periods. Two stochastic models – BB and GBM, and LSTM perform reasonably well in handling the volatility in platinum price and random market behavior. The simulation models provide complementary insights: GBM captures the average price trajectory, FBM integrates long-term dependencies and memory effects, and BB highlights mean-reversion trends, collectively emphasizing platinum’s sensitivity to macroeconomic, geopolitical, and industrial factors across these periods.

Figure 9. Comparison of LSTM, GBM, FBM and BB methods for ten periods (platinum)



In greater detail, Table 3 illustrates the performance of various forecasting models (GBM, FBM, BB, and LSTM) over ten significant financial and geopolitical crisis periods, using precious metals. It provides several performance metrics for each model: MAPE and RMSE. The table uses bolded values to denote the model with the lowest MAPE (Mean Absolute Percentage Error) for each specific crisis period and commodity. The rationale for prioritizing MAPE over RMSE (Root Mean Square Error) in this context is its interpretability and comparability across different periods and commodities. The Hurst Exponent, which helps indicate the degree of long-term memory in time series, is also shown for each period. Firstly, the findings conclude that the Hurst exponent is above 0.5 in all commodities and in each period.

Gold shows a relatively high Hurst exponent across most periods (0.536 to 0.744), indicating a persistent behavior with long-term trends rather than random movements. GBM performs well in terms of lower MAPE in most periods, indicating its superiority in capturing non-linear patterns and long-term dependencies. GBM is designed to model price changes as a continuous-time stochastic process with geometric returns, making it better suited for periods with short-term predictability and moderate volatility.

The price of silver shows a relatively high Hurst exponent across most periods from 0.588 to 0.751, indicating a persistent behavior with long-term trends rather than random movements. Consistently, LSTM outperforms stochastic models in terms of both MAPE and RMSE, making it the best model for long-term prediction of silver price. Palladium consistently shows high Hurst values indicating strong trend persistence and less random behavior. LSTM and BB

dominate in terms of accuracy across almost all periods, indicating their ability to adapt to long-term trends and short-term volatility.

Platinum exhibits Hurst exponents mostly between 0.572 to 0.747, indicating a mix of random and persistent behaviors depending on the period. Two stochastic models (BB and GBM) and LSTM perform reasonably well in terms of both MAPE and RMSE, in handling volatility in platinum price and random market behavior.

Table 3. Performance comparison between different periods

Periods	Hurst Exponent	GBM		FBM		BB		LSTM	
		MAPE	RMSE	MAPE	RMSE	MAPE	RMSE	MAPE	RMSE
		Gold							
1 st	0.536	1.829	8.086	1.027	4.908	1.029	4.856	8.180	34.661
2 nd	0.531	3.950	19.103	5.197	24.500	5.158	24.638	5.482	26.095
3 rd	0.526	10.118	31.752	14.465	44.940	14.093	43.964	30.562	89.867
4 th	0.579	33.502	254.512	26.748	211.805	27.081	213.585	26.968	211.901
5 th	0.641	12.168	144.811	13.422	184.16	13.471	183.703	38.526	447.223
6 th	0.695	7.494	153.771	12.425	234.534	12.586	237.447	40.496	680.073
7 th	0.752	51.231	669.766	32.363	415.901	32.071	412.005	13.299	180.332
8 th	0.744	5.469	92.173	9.761	159.161	9.860	161.186	10.315	166.607
9 th	0.740	5.269	121.812	8.918	183.723	8.684	179.927	10.697	214.002
10 th	0.742	5.344	137.379	8.331	202.651	8.265	201.361	13.362	296.705
		Silver							
1 st	0.642	8.810	0.531	32.232	1.930	10.659	0.672	7.663	0.473
2 nd	0.619	4.912	0.289	33.021	1.889	8.507	0.484	5.472	0.326
3 rd	0.612	13.289	0.874	21.725	1.291	13.528	0.983	7.999	0.621
4 th	0.588	28.206	3.951	51.869	3.681	40.623	4.818	27.043	4.172
5 th	0.623	41.783	6.510	35.798	5.760	31.648	5.413	34.398	7.583
6 th	0.678	12.468	5.191	17.212	7.452	11.809	5.501	41.752	14.835
7 th	0.751	101.448	18.772	69.478	12.777	70.878	12.941	62.066	11.312
8 th	0.751	13.202	2.522	51.305	9.514	12.758	2.311	10.603	2.088
9 th	0.747	20.127	5.740	42.107	10.469	25.888	6.963	30.502	8.000
10 th	0.739	8.203	2.210	12.169	3.441	4.853	1.501	12.144	3.062
		Palladium							
1 st	0.645	8.344	15.907	6.828	12.620	6.486	12.002	6.826	12.025
2 nd	0.647	9.644	21.707	9.178	23.174	9.568	23.389	9.148	22.444
3 rd	0.659	26.629	103.114	30.593	119.123	32.360	125.437	38.362	141.49
4 th	0.708	226.562	710.288	62.937	207.549	65.266	212.036	35.255	198.094
5 th	0.824	101.038	306.362	79.267	240.720	79.472	241.799	39.431	147.545

Periods	Hurst Exponent	GBM		FBM		BB		LSTM	
		MAPE	RMSE	MAPE	RMSE	MAPE	RMSE	MAPE	RMSE
		Gold							
6 th	0.813	35.181	261.284	17.350	129.563	17.580	131.115	19.964	157.572
7 th	0.804	35.113	297.757	11.972	98.435	11.558	95.087	48.274	341.593
8 th	0.797	19.540	351.401	29.916	503.936	30.755	511.519	47.165	673.143
9 th	0.846	34.044	829.744	14.129	351.779	13.890	346.982	22.383	615.15
10 th	0.847	62.421	774.134	46.798	577.288	46.180	569.128	75.977	917.27
		Platinum							
1 st	0.572	2.817	16.580	2.678	15.888	2.644	15.414	14.531	65.322
2 nd	0.560	4.297	21.326	4.574	22.153	4.396	21.495	5.016	25.359
3 rd	0.549	14.729	61.313	12.596	52.527	13.001	54.285	9.852	40.983
4 th	0.530	38.553	488.045	39.502	496.178	39.452	496.439	44.194	524.863
5 th	0.624	77.503	1039.87	58.751	787.285	58.646	785.975	23.152	446.722
6 th	0.686	18.859	353.395	9.754	184.364	9.803	185.182	61.443	1063.30
7 th	0.719	52.978	663.511	30.618	388.020	30.055	380.529	34.802	430.506
8 th	0.709	17.027	172.620	8.318	87.643	8.551	90.072	6.074	63.216
9 th	0.706	10.281	136.804	12.326	159.665	12.430	160.858	13.305	170.175
10 th	0.697	12.628	131.794	9.661	100.074	9.327	96.592	43.711	471.865

1st: Mexican Peso Crisis, 2nd: Samba Effect, 3rd: Asian Financial Crisis, 4th: 2000s Commodities Boom, 5th: 2008 Global Financial Crisis, 6th: European Debt Crisis, 7th: Russian Financial Crisis, 8th: Cryptocurrency Bubble, 9th: COVID-19 Pandemic, 10th: Russia-Ukraine Conflict

CONCLUSION

This study analyzes the precious metal prices forecasting during macro-economic periods using machine learning and traditional stochastic methods such as LSTM, BB, GBM, and FBM. The conclusion of the study is that while stochastic models like GBM and BB are effective for capturing moderate volatility and random market behavior, LSTM consistently outperforms these models in handling the complex, non-linear relationships that characterize precious metal markets. These findings underscore the importance of selecting forecasting models that align with the specific dynamics of the commodity and the market conditions.

The findings of this study not only enhance our understanding of predictive methodologies for precious metal markets, but also carry significant policy and practical implications. The persistent behavior observed through the Hurst exponent across all commodities and periods underscores the long-term

trends present in precious metal prices, which are critical for strategic planning by investors, industries, and policymakers. The superior performance of machine learning models, particularly LSTM, highlights the need for embracing advanced forecasting techniques in financial markets, especially for commodities characterized by non-linear patterns and market complexities.

For policymakers, the insights from this study can guide the development of more informed and adaptive financial regulations. The predictive capabilities of the LSTM model can assist central banks and financial regulators in monitoring market dynamics, mitigating risks associated with commodity price volatility, and formulating policies to stabilize economic conditions during turbulent macroeconomic periods. Furthermore, the superior performance of GBM and BB in specific scenarios suggests that these models can complement machine learning approaches, offering robust tools for policy-driven simulations and scenario analyses.

Based on the findings of this study, several directions for future research can be pursued to enhance the prediction accuracy of precious metal prices. Additionally, integrating macroeconomic indicators such as inflation rates, interest rates, geopolitical risks, and market volatility indices into the predictive framework can provide a more comprehensive context for price movements. By incorporating these factors as features in machine learning models, future studies can enhance prediction accuracy while offering deeper insights into the interplay between macroeconomic conditions and precious metal markets.

Furthermore, future studies are encouraged to incorporate traditional benchmark models, such as ARIMA, to compare their performance with advanced forecasting models like GBM, FBM, BB, and LSTM. This approach would enhance the robustness of findings and contribute to a more comprehensive understanding of forecasting methods under different market conditions.

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AI AND ITS SUCCESSFUL IMPLEMENTATION IN ORGANIZATIONAL PROCESSES AS A DE- VELOPMENT STIMULUS IN THE ECONOMY OF DECOUPLING

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The successful implementation of artificial intelligence (AI) in organizational processes can serve as a powerful developmental stimulus within the framework of the economy of decoupling. This process requires deliberate and focused attention. A critical success factor lies in the workforce, specifically in their acceptance of AI, its active utilization, and its integration into all available organizational activities and processes. Within the scope of our research, we performed the following: 1. identified the direct and positive contribution of AI in the enterprise processes related to the economy of decoupling, and 2. presented several theoretical models that delineate the process of employee acceptance and active adoption of AI. Nevertheless, the current pace of AI development is so rapid that even systematic studies published last year often reference concepts of generative AI contribution to enterprise processes and AI adoption that are relatively outdated, originating from two or three years ago. Therefore, the aim of this article was twofold: first, it was to identify AI contributions to specific enterprise processes that have a direct and positive impact on the economy of decoupling, and second, to identify and describe the models that ex-

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plore the adoption of the most advanced AI technologies. We followed the principles of systematic literature search in relevant databases, including EBSCO, Scopus, Web of Science, and Google Scholar. Firstly, we found that AI could contribute to the economy of decoupling in the following specific processes: supply chain optimization, cost reduction, boosting renewable energy utilization, process optimization and others. Our second findings revealed that theoretical frameworks and models nearly 50 years old, such as the Theory of Planned Behavior and the Technology Acceptance Model (TAM), continue to be applied and validated in the context of generative AI concepts that are less than three years old. Similarly, the two-decade-old Unified Theory of Acceptance and Use of Technology (UTAUT) remains widely utilized. AI will play a crucial role in advancing the economy of decoupling, with its successful application largely dependent on individual acceptance and subsequent use by employees within specific organizations. However, our understanding of these dynamics is still insufficient, underscoring the need for further research.

Keywords: *AI contribution to the economy of decoupling, AI adoption, AI literacy, technology acceptance*

JEL classification: *J24, O31, O33.*

INTRODUCTION

The development of Artificial Intelligence (AI) in recent years has led to its active implementation in the workflows of many companies, as it allows for the improvement of processes, reduction of costs and gaining a competitive advantage. Generally, the term “Artificial Intelligence” refers to advanced computer systems that mimic the cognitive functions of the human brain, such as learning, reasoning, and planning (Ludger, 2009).

Its potential to serve as a catalyst for sustainable economic growth is particularly evident in the context of decoupling — a process in which economic activities can continue to grow without causing increased harm to the environment, typically through improvements in efficiency or resource use (Parrique et al., 2019). First of all, a successful integration of AI into organizational processes can optimize resource efficiency, helping to reduce waste and energy use. For example, based on an analysis of large volumes of real-time data, AI can enable accurate forecasting and optimize resource efficiency across vari-

ous stages of production, as well as allow for the development of better waste reduction strategies (Sikander, 2024). Additionally, artificial intelligence, through machine learning and data mining techniques, helps organizations improve their business performance, enhance organizational efficiency, and solve a variety of complex engineering and financial problems (Pereira et al., 2021). Furthermore, AI is pivotal in the transition to renewable energy, which is one of the aspects of decoupling. For example, AI-based models are used to predict renewable energy output, ensure better integration of solar and wind power into the grid, and optimize energy consumption (Rashid et al., 2024). AI also plays a significant role in the development of smart cities, as it helps manage traffic, design more convenient infrastructure, optimize energy use in buildings, lower emissions in urban areas, and monitor air quality (Herath, Mittal, 2022).

Despite all the advantages, not all companies are ready for such transformations. This process can be hindered by various challenges that companies face when implementing new technologies, such as a lack of financial resources, knowledge, or infrastructure (Venkatesh, 2022). Research shows that employee resistance to change can be a significant challenge when implementing new processes and technologies within an organization (Weber et al., 2022). Scholars attribute this resistance to various factors. For instance, employees may feel threatened by automation and the possibility of job displacement, or may remain skeptical about the benefits of AI (Li et al., 2023). Several comprehensive models have been used to explain the factors influencing employees' adoption of AI tools. While these models are mostly general, they are used to study the willingness to adopt a wide range of emerging technologies. In the following paragraphs, we describe these models of adoption in more detail, as well as the specific factors that they consist of.

TAM MODEL

This model was first introduced by Fred Davis in 1986 (Davis, Bagozzi & Warshaw, 1989). According to this model, behavioral intention to use new technology is predicted by two main factors: Perceived Usefulness (PU) and Perceived Ease of Use (PEoU). The authors define perceived usefulness as “the degree to which a person believes that using a particular system would enhance their job performance” (Davis, 1989). Meanwhile, perceived ease of use reflects a person's expectation of how easy or difficult it will be to learn and use the new technology (Davis, 1989).

THEORY OF PLANNED BEHAVIOR

Another extension of the Theory of Reasoned Action is the Theory of Planned Behavior (TPB). This model posits that an individual's intention to engage in specific behavior, such as adopting new technologies, is influenced by three primary factors: attitudes, subjective norms, and perceived behavioral control (Ajzen, 1991).

Originally developed as a general psychological model aimed at understanding human behavior, TPB has been widely adopted across diverse disciplines and contexts. Within the domain of technology adoption, it has been applied to investigate willingness to use mobile services (Yang & Jolly, 2009), big data (Zaman et al., 2021), AI (Wang et al., 2024) and many other technologies.

UNIFIED THEORY OF ACCEPTANCE AND USE OF TECHNOLOGY

In 2003, Venkatesh et al. conducted a comprehensive analysis of existing models exploring technology acceptance, and developed a unified model known as the Unified Theory of Acceptance and Use of Technology (UTAUT). This framework identifies four key determinants of an individual's intention to use information technology: performance expectancy, effort expectancy, social influence, and facilitating conditions (Venkatesh et al., 2003).

Applying a systematic literature review approach, our aim is twofold: 1. to identify AI contributions to specific enterprise processes that have a direct and positive impact on the economy of decoupling, and 2. to identify and describe models that explore the adoption of the most advanced AI technologies.

This research will offer useful insights for organizations, policymakers and researchers interested in promoting sustainable economic growth through technological innovation.

METHODOLOGY

At the outset of our study, we aimed to identify the impact of artificial intelligence adoption on the economy of decoupling. In order to achieve this, we applied a systematic review search approach across major academic databases: EBSCO, Web of Science, Scopus, and Google Scholar. Using the keywords “artificial intelligence” AND “impact” AND “economic sustainability”, we

identified a set of studies confirming the link between AI adoption and the economy of decoupling, forming the basis for further analysis of AI adoption models. To identify these models, we conducted another systematic review search in the same databases, using the following keywords and their combinations: “AI”, “artificial intelligence”, “AI competence”, “AI literacy”, “AI adoption”, “AI accept”, “AI acceptance model”, and “individual AI acceptance”*. Based on abstract analysis, we selected the most relevant studies and performed a manual search (cross-referencing).

The same process was applied to identify the factors influencing AI adoption. The first step included keywords in search and their combination: “AI”, “artificial intelligence”, “AI competence”, “AI literacy”, “AI adoption”, “AI accept*”, “AI acceptance model”, and “individual AI acceptance”. The second step included a manual search of the relevant articles, and cross-referencing. We targeted the most advanced generative AI models such as ChatGPT, Claude, Gemini, and others, therefore we narrowed our search to the period between 2022 and 2024, when these new AI technologies emerged.

RESULTS

First, our analysis revealed an increase in the studies examining AI use in the recent years, highlighting the growing popularity of this topic. Since AI technologies are developing extremely fast, we focused on the most recent literature, including the papers published between 2022 and 2024. These studies exhibit significant variability in their methodologies, theoretical frameworks, target populations, and the specific AI tools used as examples. In order to provide a structured overview, we categorized the reviewed articles based on the theoretical models they employed.

Based on the article analysis, we identified that AI contributes to the development of the economy of decoupling in various ways. The results of this analysis are summarized in Table 1. Most authors highlight that AI, through data analysis and automation, enables process optimization, leading to cost reduction or, alternatively, increased efficiency at the same cost level. Additionally, AI has a positive environmental impact, particularly by reducing waste and energy consumption. Some studies also provide more specific examples, such as AI-driven efficiency improvements in marketing processes.

Table 1: Studies on how AI contributes to the development of the economy of decoupling

Contribution	Study
Supply chain optimization	S. Wamba-Taguimdje et al., 2020; M. G. Dancausa Millán, M. G. Millán Vázquez de la Torre, 2024
Cost reduction	Szedlak, Leyendecker, Reinemann, Kschischo & Pötters, 2021
Process optimization	Szedlak, Leyendecker, Reinemann, Kschischo & Pötters, 2021
Boosting renewable energy utilization	Manuel, Kehinde, Agupugo & Manuel, 2024
Task automation and increased efficiency	Wamba, Guthrie, Queiroz & Minner, 2023; Gurjar, Jangra, Baber, Islam & Sheikh, 2024
Reduction in energy consumption, pollution, and waste	Chen, Wang & Wang, 2024; Hong & Xiao, 2024
Personalized recommendations	Wamba-Taguimdje, Wamba, Kamdjoug & Wanko, 2020
Individual digital marketing	Gurjar, Jangra, Baber, Islam & Sheikh, 2024

In the second part of our analysis, we found that most studies predominantly rely on the Technology Acceptance Model, as summarized in Table 2. The first study that we analyzed was conducted on a sample of 784 ChatGPT users in China (Ma, Wang, Li, Wang & Wang, 2024), utilizing partial least squares and structural equation modeling methods. The findings validated the overall TAM framework, confirming that perceived ease of use and perceived usefulness influence behavioral intention to use AI, which subsequently impacts actual use behavior.

The second study (Limna, Kraiwanit & Chumwatana, 2024), although limited by its small sample size, supported these findings. It employed in-depth interviews with managers in Bangkok, during which respondents highlighted critical factors for adopting ChatGPT into their companies' workflows. These factors included its intuitive interface and user-friendly design (enhancing perceived ease of use), as well as business benefits (components of perceived usefulness). The Technology Acceptance Model was also used as the theoretical basis in the study by Duong, Vu & Ngo (2023), based on a sample of students from Vietnamese universities. The study confirmed the model and demonstrated that effort expectancy (similar to perceived ease of use) positively affects behavioral intentions to use ChatGPT. Additionally, it was found that the knowledge level serves as a mediator in this model. A study conducted on students in China also confirmed the TAM model. It showed that perceived

usefulness and perceived ease of use influence behavioral intentions to use AI coding assistant tools (Pan, Xie, Liu & Xia, 2024). This study also extended the original model and found that both predictors are affected by perceived trust in AI and perceived risks, and demonstrated that self-efficacy has a significant influence on perceived ease of use.

Table 2: Studies based on the TAM model with methodologies used, specific AI and sample

Study	Model applied to explain AI adoption	Factors, identified to have influence on AI adoption	Used Methodologies	AI Tool used as example	Sample
Ma, Wang, Li, Wang & Wang 2024	TAM	Perceived usefulness, Perceived ease of use	Partial least squares and structural equation modeling methods	Chat-GPT	ChatGPT users in China
Limna, Kraiwanit & Chumwatan, 2024	TAM	Perceived usefulness, Perceived ease of use	In-depth interviews and documentary analysis	Chat-GPT	Business owners and managers from Thailand
Duong, Vu & Ngo, 2023	TAM	Effort expectancy	Confirmatory factor analysis	Chat-GPT	Students from Vietnamese universities
Pan, Xie, Liu & Xia, 2024	Extended TAM	Perceived usefulness, Perceived ease of use, Perceived trust, Perceived risks and self-efficacy	Exploratory and confirmatory factor analysis, structural equation modeling	AI Coding Assistant Tools	College students in China

Source: Authors, 2024

Another group of articles identified during our analysis focused on the use of UTAUT and the Theory of Planned Behavior, as shown in Table 3. A study based on employees working in a social development organization in India

confirmed that UTAUT can be applied in AI adoption research, and confirmed the influence of all core factors of the model on the individuals’ intention to use AI tools: performance expectancy, effort expectancy, facilitating conditions, and social influence (Jain, Garg & Khera, 2022). Additionally, the model was extended with the variable “AI aversion”, and its impact on the use of AI-enabled tools was statistically significant.

The applicability of the UTAUT model was further demonstrated by a study conducted by Ibrahim et al. (2024), which involved healthcare workers in Jordan. The results confirmed that performance expectancy, effort expectancy, and facilitating conditions positively influence the behavioral intention to use AI-based healthcare systems. However, the impact of social influence was not statistically significant. A notable feature of this study was the inclusion of emotional intelligence as a variable, which is not typically part of the UTAUT model, but was found to have a significant positive effect on behavioral intention.

Table 3: Studies based on the UTAUT model or combination of models

Study	Model applied to explain AI adoption	Factors, identified to have influence on individual AI adoption	Used Methodologies	AI Tool used to describe	Sample
Jain, Garg, Khera & 2022	UTAUT	Performance expectancy, Effort expectancy, Facilitation condition, Social influence, AI aversion	Partial least squares	-	Employees working in a social development organization in India
Ibrahim et al., 2024	UTAUT	Performance expectancy, Effort expectancy, Facilitation condition, AI aversion, Emotional intelligence	Partial least squares and structural equation modeling methods	-	Healthcare workers in Jordan
Anditama & Hidayanto, 2024	UTAUT and extended TAM	Attitude, Performance expectancy	Partial least squares and structural equation modeling methods	AI Coding Assistant Tools	Software Developers in Indonesia

Study	Model applied to explain AI adoption	Factors, identified to have influence on individual AI adoption	Used Methodologies	AI Tool used to describe	Sample
Ivanov et al., 2024	TPB and TAM	Attitude, Subjective norms, Perceived behavioral control, Strengths of Gen-AI, Benefits of Gen-AI and Risks of Gen-AI	Partial least squares and structural equation modeling methods	GenAI Tools like ChatGPT	Lecturers and students around the world
Jiao & Cao, 2024	TPB and TAM	Attitude, Subjective norms, and Perceived behavioral control, Perceived usefulness, Perceived ease of use	Confirmatory factor analysis, structural equation modeling	AIAD (DALL-E, Imagen, Midjourney, and DreamStudio)	Chinese designers

Source: Authors, 2024

In the study by Anditama & Hidayanto (2024), UTAUT was integrated with an extended TAM. The results indicated that attitude and performance expectancy significantly influenced the behavioral intention to use coding AI assistants in a sample of Indonesian software developers. However, the influence of other factors, including social influence, facilitating conditions, and effort expectancy, was not confirmed. The model was also expanded to include the variable “AI knowledge”, but the hypothesis that it would significantly impact behavioral intention was rejected.

In the study by Ivanov et al. (2024), which involved students and lecturers from various countries, a model combining TAM and TPB was tested. It was confirmed that attitude, subjective norms regarding generative AI, and perceived behavioral control positively influenced the intention to use generative AI tools. The model was also enhanced by including factors such as the strengths and benefits of generative AI, which were found to significantly impact attitude, subjective norms, and perceived behavioral control. Additionally, the risks associated with generative AI were shown to affect attitude and perceived behavioral control, while the weaknesses of generative AI did not have a significant effect on any of the variables.

The combination of TAM and TPB was also applied in the study by Jiao and Cao (2024), which investigated the use of tools for Artificial Intelligence-Aided Design (AIAD) among a sample of Chinese designers. The results indicate that attitude toward AI, subjective norms, and perceived behavioral control positively impact the intention to use AI tools. Furthermore, perceived usefulness was found to positively correlate with attitude, while the impact of perceived ease of use was less significant. The study also confirmed that the knowledge level has a moderating effect on the relationship between attitude and intention to use AI tools.

DISCUSSION

The findings of our study indicate an increase in the number of studies exploring AI use and its acceptance over the past two years. These studies target diverse professional groups and are conducted across various countries. Some studies focus on specific AI tools, providing participants with a more practical understanding of their usage, with a predominant focus on ChatGPT, which has emerged as the most widely recognized and practically used generative AI tool.

This article aimed to examine the existing literature, which we achieved by identifying the main AI contributions to the economy of decoupling and to models, and by analyzing the factors by which they are complemented in modern research.

We found that AI could contribute to the economy of decoupling in the following specific enterprise processes: supply chain optimization, cost reduction, boosting renewable energy utilization, process optimization, task automation and increased efficiency, reduction in energy consumption, pollution, and waste. The second group of results shows that TAM remains one of the most widely used theories to assess the acceptance of AI technologies. However, this model is often supplemented with various factors, such as perceived trust in AI, perceived risks, and self-efficacy, as well as strengths, benefits, and risks of AI. Additionally, it is frequently combined with other models, such as the Theory of Planned Behavior model. The TPB model alone is used less frequently for studying the factors influencing AI tool adoption, as its core components — attitudes, subjective norms, and perceived behavioral control — do not account for many other relevant factors. Nevertheless, the influence of these three components has been consistently validated. The model has also been enhanced by incorporating factors such as the strengths and benefits of

AI, which have been shown to significantly affect attitudes, subjective norms, and perceived behavioral control (Ivanov et al., 2024).

Based on the findings of our research, UTAUT emerges as the most comprehensive model. The studies analyzed in our research consistently confirmed that the influence of factors used in these models, such as performance expectancy, attitudes, effort expectancy, and facilitation conditions, significantly impacted the behavioral intention to use AI across multiple industries.

However, exceptions were observed in studies conducted among medical professionals in Jordan (Ibrahim et al., 2024) and software developers in Indonesia (Anditama & Hidayanto, 2024), where social influence did not exhibit a statistically significant effect. This discrepancy suggests that this variable can have a significant impact only in professions that involve a high level of social contact (Kelly, Kaye & Oviedo-Trespalacios, 2023).

Although older technology adoption theories remain validated and widely applied to explain AI acceptance, they may not fully account for the complexities of modern AI technologies, highlighting the need for theoretical updates. Our research findings support the growing efforts to improve these models and make them more adaptable to the specific characteristics of AI tools. In particular, the studies we analyzed revealed that AI aversion negatively impacts AI adoption (Jain, Garg, Khera & 2022). Furthermore, both perceived usefulness and perceived ease of use were found to be influenced by perceived trust in AI and perceived risks (Pan, Xie, Liu & Xia, 2024). Additionally, self-efficacy was shown to have a statistically significant effect on perceived ease of use.

While we have identified that researchers often improve existing models with new variables, modern AI acceptance constructs are still rare, indicating that our current understanding of this phenomenon remains relatively superficial. Nevertheless, it is worth mentioning that models specifically designed for AI technologies are beginning to emerge, such as the AI device use acceptance model (AIDUA) (Gursoy et al., 2019). However, research on the effectiveness of these newer models in practice is currently limited.

Our research has its limitations. In particular, we examined a limited number of studies, each focused on different samples. Therefore, this may limit the ability to generalize the results on a global level. The time constraints are also worth mentioning, and as AI technologies are rapidly evolving, the study may not reflect the latest changes in AI trends or tools.

We see significant potential in further research of factors influencing the adoption of AI, particularly within the framework of a decoupling economy. This area of research is crucial, as AI serves as a powerful instrument for fostering economic growth while minimizing environmental impact. By integrat-

ing AI technologies, businesses can optimize their operations, reduce waste and lower costs, thereby promoting economic sustainability with reduced ecological consequences. Further exploration of the factors influencing AI adoption can accelerate its implementation in organizations, leading to significant improvements in resource efficiency and emission reductions, which are key components of the economy of decoupling (Sikander, 2024). For instance, AI can streamline production processes, forecast consumer behavior and enhance logistics (Herath & Mittal, 2022). These advancements enable businesses to not only cut costs and boost productivity, but also align with the principles of sustainable development.

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THE ROLE OF ARTIFICIAL INTELLIGENCE IN EMAIL MARKETING

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Artificial intelligence (AI) has become an integral component of most industries, including email marketing. Despite its potential, the role of AI in marketing remains underdeveloped, prompting questions about the extent to which tasks should be delegated to AI tools. This study examines the benefits, drawbacks, and risks of AI in the email industry.

Email marketing has evolved significantly, and AI-powered tools have recently been integrated following the breakthroughs by OpenAI. The objective of this study is to assess the effectiveness and reliability of AI tools in the field of email marketing. In particular, the study aims to investigate whether AI can achieve tangible results with minimal human assistance.

In order to achieve this objective, the research involved multiple email A/B tests comparing AI-generated and human-created subject lines. These tests were conducted both times by including about 2300 participants connected to marketing.

The study shows how the conversion rates of newsletters vary for AI-generated and human-generated subject lines, and the results provide insights into the current role, limitations, and benefits of AI in email marketing. As AI technology rapidly advances, it is crucial to learn and adapt so as to maximize its potential benefits, ensuring competitiveness and future development.

Keywords: artificial intelligence (AI), email marketing, content creation, A/B testing, audience engagement

JEL classification: L86, M15, M31, M37, O33

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INTRODUCTION

Despite the ascendance of social media as a dominant advertising platform, email marketing remains a highly effective tool. As reported by the Radicati Group, there are over four billion email users worldwide, with email being a fundamental tool for online activities, including social networking and e-commerce. Email marketing has been demonstrated to offer a high return on investment, with average ratios of 41:1 in the EU and 36:1 in the USA (Litmus, 2021).

Email marketing is a form of direct marketing that facilitates communication between businesses and consumers through the dissemination of commercial messages (Mohammadi et al., 2013; Thomas, 2022). The effectiveness of email marketing is evidenced by its high delivery rates (80%-90%), ease of tracking metrics (such as open and click-through rates) (Mittal, 2023), and higher conversion rates compared to social media (HubSpot, 2022). It can be reasonably assumed that email subscribers are more likely to engage with and purchase products than social media followers. A study conducted by an e-commerce software firm revealed that 4.24% of visitors from email campaigns were likely to make a purchase, in comparison to 2.49% from search engines and 0.59% from social media (Monetate, 2014).

Furthermore, email marketing offers a degree of stability, in contrast to social media, where follower numbers can fluctuate considerably (Budac, 2016). For instance, Twitter's rebranding to X resulted in significant alterations and a notable decline in the number of advertisers. This underscores the importance of diversifying marketing channels (HubSpot, 2023).

There are a number of different types of email marketing campaigns, including newsletters, welcome emails, and promotional emails, each of which has its own unique benefits. Despite certain disadvantages, including renderability issues and the risk of unsubscribes, email marketing remains a powerful tool for achieving measurable results and engaging directly with customers (Dania, 2017).

THEORETICAL BACKGROUND

In the contemporary world, where change is occurring at an accelerated pace, maintaining a competitive advantage is of paramount importance for all businesses, including email marketers. The application of advanced technologies, such as artificial intelligence (AI), offers significant advantages in email marketing, including the enhancement of personalization, data analysis,

content creation, and A/B testing (Haleem et al., 2022). Artificial intelligence has transformed email marketing by enhancing the effectiveness and speed of campaigns (Sadeq et al., 2023). These tools automate tasks and suggest relevant keywords, topics, and content ideas, thus reducing the time needed for brainstorming and creative processes (Priyanga, 2023).

AI-GENERATED CONTENT IN SOCIAL MEDIA AND ADVERTISING

AI-generated content (AIGC) has demonstrated its competitiveness with human-generated content across diverse social media platforms. For example, studies indicate that AIGC scored higher in user preference, call-to-action effectiveness, and emotional responses on platforms such as Facebook, compared to human-generated content. However, this advantage is less evident on platforms like Twitter and Instagram, where brevity often defines engagement (Davenport et al., 2020). Additionally, AI tools for visual design have shown promising results in comparison to human designers. Performance assessments, such as A/B testing on Facebook and Instagram, reveal that AI-generated visual advertisements can achieve comparable outcomes to those designed by humans (Campbell et al., 2022).

CONSUMER PERCEPTION AND ENGAGEMENT

Research indicates that consumers are more likely to share AI-generated content than human-generated content. This trend is attributed to the innovative appeal and heightened emotional arousal that AI-generated content evokes (Berger, 2014). Furthermore, AI-generated advertisements can positively influence customer engagement both psychologically and behaviorally. However, the degree of emotional arousal elicited by the advertisement and whether it is explicitly labeled as AI-generated are critical moderating factors influencing these effects (Campbell et al., 2022).

EFFECTIVENESS IN MARKETING COMMUNICATIONS

AI-driven systems have proven adept at automating content creation by leveraging customer data to personalize messages and optimize marketing strategies. Personalization through AI not only enhances customer engagement,

but also bolsters the effectiveness of marketing campaigns (Davenport et al., 2020). The continuous improvement of content quality and relevance through AI integration is particularly advantageous in dynamic marketing environments (Davenport et al., 2020).

EMAIL CONTENT CREATION WITH GENERATIVE AIS

The advent of generative AI models has significantly transformed the process of content creation, impacting various fields, including email content creation. Tools such as ChatGPT and Bard generate content that is human-like in its style, and which can be written in a variety of different ways. This has the effect of revolutionizing the way in which writers interact with texts (Radford et al., 2021). In contrast to traditional AI classifiers, generative AI is capable of generating novel objects or texts, thereby opening up vast avenues for creative writing (Wiles, 2023).

The generation of engaging email content is a time-consuming process that necessitates collaboration. Generation of content ideas by AI accelerates the process by providing numerous outlines, ideas, and keyword suggestions, thereby saving hours of work (Li et al., 2021). Additionally, AI tools can enhance text by rephrasing it to be more engaging (T. Ohanian, 2019). While generative AI can create complex email campaigns, it is essential to conduct thorough proofreading so as to ensure the quality of the output. Artificial intelligence (AI) tools can generate subject lines and longer texts based on content, keywords, and brand style. Nevertheless, it is possible that AI-generated subject lines may exhibit recognizable patterns due to their pattern-based generation (AIContenty, 2023).

In email marketing, the use of visuals is of paramount importance, given the need to capture and hold the attention of the recipient. Generative AI is particularly adept at creating images tailored to specific projects and customer interests, selecting colors to elicit desired responses, and maintaining campaign consistency. The ability to edit AI-generated images affords flexibility in content creation (Qian, 2022).

Although previously the domain of graphic designers, AI tools facilitate the process by presenting multiple variations in a relatively short time. However, in the absence of adequate knowledge and experience, the efficiency and quality of AI-generated content may be compromised.

Despite inherent limitations, AI-generated content can be a valuable tool in email marketing when employed in a strategic and thoughtful manner. The

ability of AI to engage audiences effectively, thereby fostering loyalty and trust, hinges on an understanding of and responsiveness to the aforementioned issues (AIContenty, 2023).

CHALLENGES AND CONSIDERATIONS

Despite its potential, AI-generated content faces challenges related to authenticity and creativity. Human-generated content often outperforms AI when deeper originality and nuanced brand storytelling are required (Lermann Henestrosa et al., 2023). Moreover, the effectiveness of AIGC is highly contingent on the accuracy of input data, such as brand voice and target audience specifications. Challenges such as inconsistencies in content generation and maintaining a cohesive brand voice have been noted as key areas for improvement (Kocoń et al., 2023).

A/B TESTING WITH ARTIFICIAL INTELLIGENCE

A/B testing is a common method for evaluating email campaigns. It involves splitting the mailing list to determine which campaign engages better. The different versions are sent to different recipients, with the objective of measuring audience behavior under real-world conditions (Burk, 2006). Prior to the advent of AI, segmentation was frequently haphazard due to the time-consuming and error-prone nature of manual segmentation. Artificial intelligence (AI) automates this process by categorizing recipients based on information such as gender, age, purchase history, and preferences. The use of AI-powered A/B testing enables the processing of vast amounts of data in real-time, thereby facilitating more accurate and in-depth analysis (Deo, 2023).

A/B testing is a process that encompasses more than simply sending different email versions to different segments. Furthermore, it encompasses testing the optimal sending time, given that individuals check emails at various times due to the high prevalence of mobile usage. Consequently, it is not uncommon to send campaigns in the evenings or early mornings (VWO, 2023).

IMPLICATIONS FOR EMAIL MARKETING

Although the reviewed studies do not provide direct comparisons for email marketing, the insights suggest that AI-generated content could be particularly effective in contexts that prioritize personalization and data-driven strategies. AI's capacity to refine and optimize content continuously based on user data presents an opportunity for enhanced customer engagement and higher conversion rates in email marketing campaigns (Davenport et al., 2020).

METHODOLOGY

The objective of the study was to assess the efficacy and dependability of AI tools in email marketing. While acknowledging the transformative impact of AI, the research endeavored to ascertain whether AI could achieve notable outcomes with minimal human intervention. Conducted for a collaborative email design platform, the study entailed the creation and testing of emails using the company's drag-and-drop builder tool in the period from September to November. The emails were disseminated to actual subscribers, many of whom were users of the company's tools and professionals in email marketing.

The study was overseen by a consultant and email industry professionals to ensure its credibility. Its objective was to provide detailed insights that would enable meaningful conclusions to be drawn about the potential of AI in email marketing.

AI-GENERATED CONTENT VS. HUMAN-CREATED EMAIL CONTENT

In this phase of the research, the efficacy of human-created and AI-generated email subject lines was evaluated by means of two A/B tests. Both tests focused on the topic of dark mode. The human-created versions were developed by the researcher and reviewed by a colleague from the company to ensure accuracy and clarity. The AI-generated versions were similarly reviewed to ensure the same standards were met.

The participants were selected from similar marketing-related fields and their gender and age ranges were tracked to ensure fair segmentation. The email list comprised active subscribers to the company's newsletter from January to September 2023. Previous tests had confirmed the successful delivery of the email list. The segmentations were generated using an internal AI tool that

had previously demonstrated effectiveness in similar applications. Although subsequent experiments in the thesis did not rely on AI segmentation, the researcher maintains the conviction that AI can outperform human performance in email list segmentation.

In this research phase, the efficacy of human-created and AI-generated email subject lines was evaluated by means of two A/B tests, with the topic of Dark Mode serving as the focus. Each test was conducted on approximately 2,300 individuals selected from an email list. Subject line tests were sent to the same audience with different segmentations. The participants were professionals in marketing-related fields, and they were segmented by gender and age to ensure fairness.

Both human-created and AI-generated subject lines were provided with identical guidelines, content, email structure, and visual design descriptions. The test was distributed to 2,301 individuals, with an equal number allocated to each of the two segments based on gender and age.

The open rates of the emails were observed over a five-day period. The human-created subject line was sent to 1,151 recipients, while the AI-generated subject line was sent to the remaining 1,150. Both versions were scheduled for delivery on a Thursday at 3:00 p.m. Eastern Standard Time, with a one-minute discrepancy due to software limitations.

Table 1: Subject line A/B test 1.1

First Test 1.1	Human-Created Version	AI-Generated Version
1. Variable tested	Subject line	Subject line
2. Tested on	1151 recipients	1150 recipients
3. Observed for	5 days	5 days
4. Delivery time	Oct. 26 th , 15:00 PM	Oct. 26 th , 14:59 PM
5. Winning metric	Highest open rate	Highest open rate
6. Subject line	Light Up Your Emails 💡 — Introducing Our Dark Mode Email Optimization Service	Resolve Dark Mode Email Challenges with Our Review and Optimization Service

As part of the initial test, a second round of subject line A/B testing was conducted in order to validate the results. This follow-up email served as a reminder of the initial message, containing different subject lines, but the same content. To eliminate potential biases, the second test was sent out more than three weeks after the initial test, with delivery scheduled for Tuesday at 11:00 a.m.

The decision to delay the second test was made in order to prevent overloading the small, yet active email list and to maintain reader interest, as con-

secutive emails on similar topics are uncommon for our campaigns. Despite the AI tool indicating a delivery time of PM, as in the initial test, the researcher opted for AM this time, so as to evaluate the opening performance shortly after delivery. The emails were sent to 2,267 recipients, divided into two segments. The list size was slightly reduced due to unsubscribes or other factors (see Table 2).

Table 2: Subject line A/B test 1.2

First Test 1.1	Human-Created Version	AI-Generated Version
1. Variable tested	Subject line	Subject line
2. Tested on	1134 recipients	1133 recipients
3. Observed for	3 days	3 days
4. Delivery time	Nov. 14 th , 11:00 AM	Nov. 14 th , 10:59 AM
5. Winning metric	Highest open rate	Highest open rate
6. Subject line	Don't miss out; On Our Dark Mode Email Optimization Service 🌙	Reminder: Optimize Your Emails for Dark Mode with Us!

In the second phase of testing, the focus shifted to email content, with a particular emphasis on promoting a Dark Mode eBook authored by the company. In collaboration with the Head of Marketing, a comprehensive plan was developed, delineating the structure, design elements, color themes, font types, and text size of the email. In addition, keywords essential to conveying consistent messaging were identified and allocated to specific sections of the email.

Instructions for content length were provided in intervals rather than precise word counts, allowing for some flexibility in the AI tool's ability to generate content. It is noteworthy that AI-generated content exhibited a tendency towards the upper limit of these intervals, while human-created versions exhibited a tendency towards the lower end.

In addition to the principal message, the email included a description of the content of the e-book. Both AI and human versions were provided with identical resources, although the AI was permitted greater creative license to utilize synonyms, conjugations, and modify sentence structures. This resulted in notable differences between the two versions, with the AI often presenting keywords as bullet points for clarity and attention-grabbing purposes.

RESULTS

The initial test concentrated on email open rates, which represented the percentage of recipients who opened the emails. In general, open rates range from 18% to 30%, with an average of 21.33%. The subject line test yielded an impressive 44.4% open rate, which surpassed expectations. Further analysis revealed that there was a minimal difference in the number of delivered emails, which did not significantly affect the subsequent results. In particular, the email with the human-created subject line achieved an open rate of 48.1%, which was higher than the AI-generated counterpart at 40.7%. Although the observed difference was modest at 8%, it was statistically significant, indicating that the human-written subject line was more compelling. This conclusion is supported by calculations and implies that the impact of the subject line on open rates was not random.

Table 3: Subject line A/B test result 1.1

First Test 1.1	Human-Created Version	AI-Generated Version
1. Subject line	Light Up Your Emails ☹ — Introducing Our Dark Mode Email Optimization Service	Resolve Dark Mode Email Challenges with Our Review and Optimization Service
2. Successful Deliveries	1081	1073
3. Bounced	70	77
4. Soft bounces	63	62
5. Hard bounces	7	15
6. Opens	520	437
7. Opens of first 2 hours	118	114
8. Open rate	48.1%	40.7%

The email reminder focused on open rates and compared the performance of subject lines generated by AI and those created by the author. The two subject lines yielded comparable open rates, with a rate of 39.1% for the subject line created by the AI and a rate of 37.6% for the subject line created by the researcher. The marginal discrepancy in open rates (420 for mine and 405 for AI) is not statistically significant, indicating that it may be attributable to chance rather than subject line effectiveness. These minor variations are unlikely to significantly impact email marketing campaigns. Nevertheless, it is important to acknowledge that different subject lines or audience segments may yield disparate results if the test were to be repeated.

Table 4: Subject line A/B test result 1.2

First Test 1.1	Human-Created Version	AI-Generated Version
1. Subject line	Don't miss out; On Our Dark Mode Email Optimization Service 🦄	Reminder: Optimize Your Emails for Dark Mode with Us!
2. Successful Deliveries	1075	1077
3. Bounced	59	56
4. Soft bounces	55	48
5. Hard bounces	4	8
6. Total opens	420	405
7. Opens of first 2 hours	147	150
8. Open rate	39.1%	37.6%

The researchers employed a 24-hour performance tracker to monitor email opens and observe any differences resulting from the change in delivery timing. Surprisingly, this round showed better performance in the initial hours compared to the previous one. Within the first two hours, the emails garnered 297 opens, surpassing the 232 opens observed in the first two hours of the initial email delivery.

A statistically significant difference in open rates can be inferred between the two campaigns within the first two hours. In essence, the first email exhibited a notably lower open rate compared to the second, reminder email. Although the difference is relatively minor, it suggests that the second set of email delivery times was more effective for the recipients.

The second test entailed more comprehensive calculations than the first one. The objective was to assess the outcome from multiple vantage points. In addition to measuring the click-through rate, the click-to-open rate (CTOR) was also evaluated. The CTOR serves as a gauge of the effectiveness of the email's content, offering insights into audience engagement and preferences. In contrast to the overall click rate, which reflects general engagement, the CTOR provides a more nuanced understanding of how well the email's message resonates with the audience.

A typical click-through rate is approximately 5%, although this may vary depending on factors such as industry and list size. Similarly, the optimal CTOR is situated between 14% and 25%, contingent on industry standards.

The test yielded an overall open rate of 38.3%, with 2,152 subscribers successfully receiving the email and 825 opening it. The human-created subject line achieved an open rate of 39.1%, with 420 opens, while the AI-generated email boasted an open rate of 37.6%, with 405 opens. It is important to note

that the identical subject lines of the emails influenced the results, rendering the open rate an inconclusive metric in this context.

The study's findings on conversion rates align with the trends observed in open rates, with human-generated content slightly outperforming AI-generated content in driving sales. While both approaches led to successful conversions, emails with human-crafted subject lines and content resulted in a marginally higher number of purchases, suggesting that human intuition and creativity may have a stronger influence on persuasive messaging. This indicates that beyond attracting initial engagement, human-written content may be more effective at compelling recipients to take action. However, the long-term impact of AI-generated email marketing on customer retention remains an open question. Future research should focus on tracking customer engagement over extended periods to determine whether AI-generated content fosters sustained loyalty and repeat purchases. By analyzing customer lifetime value and retention rates, marketers will gain deeper insights into whether AI-generated content can maintain long-term relationships or if human-driven messaging remains superior in nurturing ongoing engagement.

Although the research did not reveal any significant discrepancies between the two versions, the human-written content demonstrated superior performance by the end of the tests. Nevertheless, it is important to acknowledge that the AI-generated versions also demonstrated satisfactory overall performance. Despite occasional preferences for different language or style, the AI's output generally met expectations. However, in real-world scenarios, my colleague's discerning eye quickly identified the AI-authored emails, noting discrepancies in vocabulary and style. Despite the provision of comprehensive brand voice guidelines, the AI encountered difficulties in fully adapting them. Notwithstanding these constraints, the AI was able to complete the assigned tasks, albeit imperfectly.

For those new to email marketing, AI could be a valuable tool initially. Nevertheless, for those with considerable experience in the field, relying solely on the tool without further editing is inadvisable. This is evidenced by the high unsubscribe rate observed, particularly with AI-generated subject lines, which reached 13 unsubscribes compared to the usual one to three. It is reasonable to posit that subscribers, such as my colleague and I, discerned the distinct vocabulary utilized by the AI, which may have contributed to a sense of dissatisfaction. While this assumption lacks empirical evidence, it suggests a potential impact on subscriber engagement.

DISCUSSION

The findings of this study provide valuable insights into the effectiveness of AI-generated email content in comparison to human-created emails. One of the most significant observations is that human-written subject lines consistently outperformed AI-generated ones in terms of open rates. This suggests that human intuition and creativity remain crucial factors in crafting engaging email subject lines. While AI tools can generate grammatically sound and semantically relevant content, they often lack the nuanced understanding of audience psychology, humor, and emotional appeal that human marketers naturally integrate into their messaging. The slightly lower performance of AI-generated subject lines may be due to their pattern-based generation, which can result in text that feels formulaic or generic to recipients.

Another notable result is that while AI-generated content performed reasonably well in open rates, it led to a slightly higher unsubscribe rate. Several factors could explain this trend. First, AI-generated emails may not always align perfectly with the expectations of the audience, particularly in terms of tone, personalization, and emotional resonance. Human-written content often contains subtle cues, such as humor, rhetorical questions, or cultural references, that make the email feel more authentic and engaging. AI, on the other hand, tends to optimize for clarity and efficiency, but may overlook these stylistic elements that contribute to brand identity and audience trust.

Additionally, while AI-powered A/B testing effectively segmented audiences and optimized email delivery timing, it may not have accounted for contextual shifts in audience behavior. Recipients may have detected an impersonal tone in AI-generated emails, leading to decreased engagement and a higher likelihood of opting out of future communications. Research suggests that audiences are more likely to remain subscribed to marketing emails when they feel a sense of personal connection with the sender. This is particularly relevant in industries where trust and relationship-building play a key role in customer retention.

The findings also highlight the importance of strategic human intervention in AI-assisted marketing. While AI can generate content at scale, it is most effective when used as a complementary tool rather than a full replacement for human creativity. The results indicate that AI-generated content can serve as a solid foundation, but requires human refinement to ensure alignment with audience expectations and brand voice. This underscores the broader implication that AI, while powerful, is not yet a complete substitute for human expertise in marketing communication.

CONCLUSION

In this phase of the study, the objective was not merely to assess the capabilities of AI in email marketing tasks; rather, it was to delve deeper into its practical role and effectiveness in real-world scenarios. A/B tests conducted on subject lines revealed noteworthy insights. While AI-generated text showed promise, the human-written versions consistently outperformed them across various metrics, indicating room for improvement in AI's ability to replicate human creativity and brand voice.

In light of the research findings, the researchers acknowledge the potential for AI-human partnerships. While AI aids in streamlining tasks and generating novel ideas, its limitations in text creation became apparent during the study. Despite AI's ability to produce functional content, the researcher found that the time and effort invested in crafting suitable prompts and correcting errors outweighed the benefits, highlighting the importance of human input in refining and guiding AI-generated output.

The study ultimately demonstrates the complementary nature of AI and human intelligence. While AI has the potential to enhance productivity and creativity, its full potential can be realized through collaborative efforts with human expertise. Continued refinement and integration of AI tools alongside human input holds the promise of achieving more impactful and satisfactory outcomes in email marketing and beyond.

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WHO WILL LEAD THE DIGITAL ECONOMY? INSIGHTS FROM GREEK AND CROATIAN STUDENTS

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Transformation to digital economy can ensure a competitive edge for economies globally. The implementation of digital economy contributes to cost reduction, labour productivity, increased innovation potentials, and adaptation of the economies to the market disturbances. The increased competitiveness and efficiency of a digitally transformed economy can open new opportunities for expansion and global collaborations. Digital economy transformation may be carried out only by human resources with adequate digital competencies. The importance of digital competencies through various sectors as essential skills in this transition is recognized worldwide. The perception and level of digital skills vary among students from different backgrounds. *This study aims to investigate the differences in self-assessment of digital skills among students of economics and business administration in Croatia and Greece.*

The main objective of this study was to assess and compare the self-assessed digital competencies of economics and business administration students in Croatia and Greece, and to analyse how the students perceive the importance of investigated digital competencies to employers. Additionally, the authors of the study aimed to identify any significant dis-

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parities among genders in terms of self-assessment perception. In order to conduct the research, the authors carried out a survey among the students of economics and business at the University of Rijeka in Croatia and the International Hellenic University in Greece. The methodology employed in this study encompassed previous studies comparing digital competencies across genders. The authors employed a structured questionnaire that rated various elements of digital competencies with Likert-type items. In the conducted analysis, the authors found significant differences between Croatian and Greek students. Croatian students generally rated their digital competencies higher than the Greek ones. Particularly, female students in Croatia displayed higher self-assessment compared to the females in Greece, suggesting a difference in educational influence on digital confidence.

The study highlights the need for the institutions to address the observed issues and to align their digital literacy programs more closely with the expectations of the global job market. Additionally, it underscores the importance of cultural and educational contexts in shaping the students' perceptions and confidence in their digital skills.

Keywords: *Higher economics education, digital competencies, self-assessment, Greece, Croatia*

JEL Classification: *C38, I23, J24*

INTRODUCTION

The global transition toward a digital economy has reshaped the requirements for workforce skills and educational priorities. Digital competencies, defined as the ability to use digital tools effectively for information retrieval, communication, and content creation, are now essential for ensuring competitive economic growth (Pan, 2015). Economies undergoing this transformation benefit from reduced operational costs, enhanced innovation, and increased adaptability to market changes (Melazija IPA, 2018). However, the successful implementation of these transitions hinges on the preparedness of human capital – specifically, the digital competencies of the future workforce (Çebi & Reisoğlu, 2020). The increasing reliance on digital tools across all sectors underscores the need for educational systems to prioritize digital literacy. The ability to navigate and leverage digital technologies has become a critical determinant of success, not only at an individual level, but also for organiza-

tions aiming to thrive in competitive markets. Governments, educators, and businesses alike recognize that bridging the digital skills gap is imperative for sustained economic development (Research in Competences Archive, 2022). This need is particularly pronounced in nations transitioning from traditional to knowledge-based economies, where digital infrastructure and human capital development are central to progress.

Higher education students, particularly those in economics and business administration, make up a representative demographic sample in this shift. They will constitute the future labour market and a part of them will probably become the leaders in creating digital strategies. The skills necessary to achieve the demands of the labour market are provided by the higher education institutions. There are numerous studies that highlight the importance of digital competencies all around the world, however, the perception and self-assessment of these skills vary significantly across countries and regions, depending on cultural, educational and socioeconomic factors. Therefore, there is a need to promote digital literacy, because of the variations due to disparities in technological adoption and different educational systems (Garcia-Fernández et al., 2020). This paper studies the digital competencies of economics and business administration students in Croatia and Greece, and aims to reveal the disparities in self-assessment, gender differences, and perceived employer expectations. The goal is to provide insights into how educational practices and policies can be aligned to meet the evolving requirements of a digitally driven economy by exploring these differences. Designing interventions that enhance digital readiness and ensure fair access to technological resources comes after understanding the regional and demographic variations (Kavanagh & Drennan, 2008).

This study aims to deal with the following two critical questions: a) how students in economics and business studies in Croatia and Greece assess their digital competence, and b) what their perceptions are of the importance of these skills to employers. The aim of the study is not to assess the students' digital competence, but rather to obtain information on how students self-assess their digital competence, i.e. their perception of their own digital competence. Additionally, we wanted to find out how the students perceive the importance of digital competence to the employers.

Croatia and Greece were chosen for this study analysis because in the European Union context they have similar socio-economic backgrounds and environment. However, their levels of digital competencies, digital infrastructure and educational policy are significantly different. According to the report on digital performance of the European Commission on the Digital Economy

and Society Index (DESI 2022), Croatia has achieved better results in terms of human capital and integration of digital technologies in education systems compared to Greece. The proposed study will enable a stronger identification of the impact of education policies and national strategies on the students' digital competencies.

This study provides reliable discussions for the integration of educational programs in higher education in line with the demands of the digital economy. The basic tool of this study is a structured survey, as well as comparative statistical analyses conducted on the data obtained. The goal of this analysis is to contribute to the broader dialogue on digital education, offering recommendations to policymakers and educators so as to enhance digital competence development across diverse contexts.

LITERATURE REVIEW

The theoretical framework of digital competencies is based on several skills, such as information literacy, collaboration, evaluation, problem-solving and content creation (Çebi & Reisoğlu, 2020). These competencies are nowadays recognized as fundamental for success in various professional fields. The role of digital competencies in organizational efficiency, innovation and reinforcing employability is highlighted in several studies (Pan, 2015). Nevertheless, contemporary literature pinpoints the necessity of recognizing the importance of digital literacy not only in educational contexts, but also in broader contexts such as necessity to be a part of the development of these skills and competencies (Schindler et al., 2017; Castro, 2019). Schindler et al. (2017) argue that integrating computer-based technologies, including web conferencing and digital games, significantly enhances student engagement, fostering behavioural, emotional and cognitive dimensions of learning. Moreover, Castro (2019) highlights the capabilities of blended learning modalities, asserting their potential in facilitating individualized learning paths and improving feedback mechanisms, thus enhancing students' digital competencies.

In order to address the real-world applications and the continuously evolving labour market demands, active learning methodologies should be implemented for the purpose of acquiring digital skills in line with the labour market demands. Digital education has continuously evolved over the past years and consequently the academic research has sparked, especially with regard to the factors that influence the development of digital skills and the use of digital tools in the classroom. Murillo-Zamorano et al. (2019) found that flipped class-

rooms significantly improve knowledge retention, skill development, student engagement, and satisfaction. Implementing this kind of methodology activated the learning and higher-order cognitive processes, directly enhancing the students' employability and readiness for the labour market. Robinson (2007) and Garcia-Fernández et al. (2020) highlight the role of Importance-Performance Analysis (IPA) in evaluating both perceived and actual competencies.

The COVID-19 pandemic had a positive impact on the acceleration of digital transformation in higher education, hastily integrating digital technologies in the teaching processes (Iivari et al., 2020; El Said, 2021; Zawacki-Richter, 2020). This rapid transition revealed significant disparities in the students' and teachers' digital competence, and disparities within the infrastructure, emphasizing the urgency of systematically assessing and developing digital competencies within higher education institutions (Bygstad et al., 2022; Tang et al., 2021). In addressing the issue of comparing the level of digital competencies between students and teachers, surprising results were obtained in the empirical study carried out by Waycott et al. (2010). The study results showed more similarities between students and staff, as opposed to revealing significant and profound differences in terms of ability and knowledge in digital competencies. The results of the five-year quality study indicated that both groups selectively adopt technology based on perceived educational utility and personal preferences. The reason for these similarities could be found in the aspiration and will for further development both in the students and teachers. In their study, Tang et al. (2021) introduced the importance of readiness factors as critical to a successful digital learning implementation, highlighting the importance of technology infrastructure and technology readiness, and online communication self-efficacy. In their study, Händel et al. (2020) explored the readiness of higher education students for digital distance learning in the context of the COVID-19 pandemic. The results of the study indicated that students with low levels of readiness experienced negative stress-related emotions and feelings of isolation. Technology readiness included inadequate equipment or skills necessary to participate in digital distance courses. The study emphasized the need for higher education institutions to consider not only technical preparedness, but also socio-emotional support systems in digital learning environments.

Furthermore, gender disparities play a significant role in shaping digital literacy. Recent systematic reviews (Spante et al., 2018; Zhao et al., 2021) stress the importance of integrating both technical skills and social practices into digital literacy definitions, advocating for gender-sensitive approaches to education. The common denominator of the literature is that female students report lower levels of confidence in their digital skills than males, even though

they have similar technical proficiency levels (Kavanagh & Drennan, 2008). This phenomenon, referred to as the “confidence gap” highlights the need for gender-sensitive approaches in digital education (Research in Competences Archive, 2022). Comparative studies have also examined regional and country differences. Students in Croatia, for example, benefit from a robust integration of digital literacy within their curricula, while students in Greece face challenges such as limited access to advanced technological tools and underfunded educational infrastructures (Melazija IPA, 2018). Moreover, higher education institutions must actively collaborate with industry stakeholders to ensure that curricula remain relevant to the demands of the labour market. Real-world experience can be provided to students through collaborative programs and internships with technology companies, helping them to improve their digital skills. Students should be able to apply their knowledge in diverse professional contexts, and this can happen through integrating digital competencies into interdisciplinary courses (Robinson, 2007). Artificial intelligence, blockchain, and big data analytics, among others, are reshaping skill requirements across industries. However, a significant investment in training the teaching staff and developing the infrastructure of higher education institutions is required to achieve this. Pan (2015) emphasizes the need for ongoing professional development programs for teachers in order to keep pace with the technological developments.

Azzopardi (2013) and Dwyer (2012) have also drawn attention to the role of digital literacy in enhancing collaboration skills, particularly in virtual and intercultural environments. Their findings suggest that enhancing digital competencies in these contexts can improve teamwork and problem-solving outcomes. Additionally, Blau et al. (2020) reveal that the digital literacy framework should concentrate not only on cognitive and social-emotional literacies, but also on technical literacies, such as the ability to quickly adopt and effectively use new technologies. In other words, it should emphasize the skills needed in the real world and the demands of the real market. Furthermore, Kavanagh and Drennan (2008) support the integration of soft skills with technical knowledge in order to better align the graduates’ abilities with employer expectations.

Banks et al. (2018) highlight the importance of adaptive learning technologies in personalizing the educational experience. These tools enhance student engagement and address individual learning gaps, enabling more effective skill development. Similarly, Pan (2015) underlines the potential of gamified learning environments in motivating students and fostering a deeper understanding of complex digital tools. Other studies, such as those by Johns (2001) and Sever et al. (2015), highlight the basic role of social and emotional intelligence in complementing digital skills. This integration equips students with

the interpersonal skills necessary for effective communication and collaboration in technology-driven environments. Cloud computing and remote working tools have also become crucial in modern education, offering new paths for teaching and learning (Banks et al., 2018). Frameworks such as the European Digital Competence Framework for Citizens (DigComp) provide a structured approach to developing digital skills across age groups and professions (Vuorikari et al., 2016). Furthermore, Zhao et al. (2021) encourage the use of digital competence frameworks, such as the European Digital Competence Framework (DigComp), as robust tools for objective assessment, complementing self-assessed competencies, and providing a balanced and accurate representation of students' abilities and readiness for the digital workforce. These frameworks highlight the importance of lifelong learning and continuous skill development in order to keep pace with the technological developments.

This study builds on these findings by exploring the comparative levels of digital competence of Croatian and Greek students, using methodologies derived from previous IPA-based research to uncover actionable insights for educators and policymakers. By examining the intersections of gender, regional context and educational practices, this research aims to contribute to the broader dialogue on digital education and inform strategies for promoting digital literacy in higher education.

DATA AND METHODOLOGY

The data was collected by means of an anonymous survey distributed to business and economics students in Croatia (HR) and Greece (GR). The survey in Croatia was conducted in 2022 at the University of Rijeka, Faculty of Economics and Business, as part of a broader research relating to migration¹. The survey included a self-assessment of the following components of digital competence: information and data literacy (DC1), communication and collaboration (DC2), digital content creation (DC3) and problem solving (DC4), as well as student's perception of the importance of digital competence to the employers (DC_EMP). The same survey was conducted in Greece in 2024 at the International Hellenic University in order to compare perceptions on the digital competence of the students in the two countries.

¹ The data were collected as part of the project "*MI – jučer, danas, sutra*" (UP.04.2.1.06.0018) and financially supported by the European Union within the European Social Fund, and are used with permission.

Only offline students were considered for this study and the final count included 663 students from Croatia (76% female and 24% male students) and 229 students from Greece (65% female and 35% male students). The average age of Croatian students was 21.16 ($SD = 1.84$), and among Greek students it was 24.03 ($SD = 9.11$). The average year of study of the students from Croatia was 2.83 ($SD = 1.43$), and of Greek students it was 2.79 ($SD = 1.45$)².

Since the study does not attempt to assess the students' digital competence, the students were asked to self-assess their competence instead. In this context, we did not attempt to make an objective assessment of competence, but the students were asked what their perception of their own competence was, and were specifically asked about their perception of the different components of digital competence. The students self-assessed the following components: DC1 – DC4 by rating a claim on each component (from 1 - Strongly disagree to 5 - Strongly agree) (Table 1), forming a Likert-type item for each component of digital competence. The claims were modified from a more comprehensive study conducted by Çebi & Reisoğlu, 2020. In addition, the students indicated how important they consider digital competence is to employers (DC_EMP) by rating one claim on this matter (from 1 - Not at all important, to 5 - Exceptionally important) (Table 2).

Table 1: Claims for self-assessing the components of digital competence

Component		Claim
DC1	Information and data literacy	I can search digital contents and information and evaluate their quality.
DC2	Communication and collaboration	I use digital technologies for communication and collaboration in an online environment.
DC3	Digital content creation	I am able to develop contents of various formats using digital technologies.
DC4	Problem solving	I solve the problems I encounter when using digital media and devices.

Note: Possible answers range from 1 - Strongly disagree to 5 - Strongly agree

Source: Authors

² Year of study in Croatia and Greece is not completely identical. In Croatia, it is calculated on the basis of passed courses/ETCS, regardless of how long it took a particular student, while in Greece the duration of study is independent of how many courses the student has passed. To ensure comparability, the year of study of graduate students in Croatia was added to the duration of undergraduate studies, while the year of study of undergraduate students remained unchanged.

Table 2: Claim about the perception of the importance of digital competence to employers

Digital competence		Claim
DC_EMP	Perception of the importance of digital competence to employers	To what extent do you think digital competence is important to employers?

Note: Possible answers range from 1 = Not at all important to 5 = Exceptionally important

Source: Authors

Since Likert-type items are of ordinal nature, non-parametric statistical methods were used.

For each of the variables, the descriptive statistics for Croatian and Greek students are presented separately. Competence components are compared graphically and numerically within and between Croatian and Greek students. The box and whiskers chart was used for graphical presentation and comparison, while different numerical measures were used as well. The Friedman test with post-hoc analysis by means of Nemenyi-Wilcoxon-Wilcox all-pairs test was used for the comparison of digital competence components among Croatian and Greek students separately. The Wilcoxon signed-rank test was added to compare the perceptions of digital competence and perceptions of labour market relevance, expressed through the perception of importance of digital competence to the employers, among the students of each country.

The comparison of digital competence and perceived importance of competence between Croatian and Greek students was done by using the Mann-Whitney test and Two-Sample Kolmogorov-Smirnov tests. In order to check whether the differences between Croatian and Greek students were present in the total population or whether they were perhaps the result of differences between females in Croatia and Greece or the differences between males in Croatia and Greece, the comparison was additionally carried out separately for female and male students.

RESULTS

The descriptive statistics on digital competence and its importance as assessed by Croatian and Greek students are presented in Table 3.

Table 3: Descriptive statistics on digital competence and its perceived importance among Croatian and Greek students

Competence	Mdn (IQR)		Mode		Min		Max	
	HR	GR	HR	GR	HR	GR	HR	GR
DC1	4 (4-5)	4 (3-4)	5	4	1	1	5	5
DC2	5 (4-5)	4 (3-5)	5	5	2	1	5	5
DC3	4 (4-5)	4 (3-5)	5	3	1	1	5	5
DC4	4 (4-5)	4 (3-5)	4	3	1	1	5	5
DC_EMP	5 (4-5)	5 (4-5)	5	5	2	1	5	5

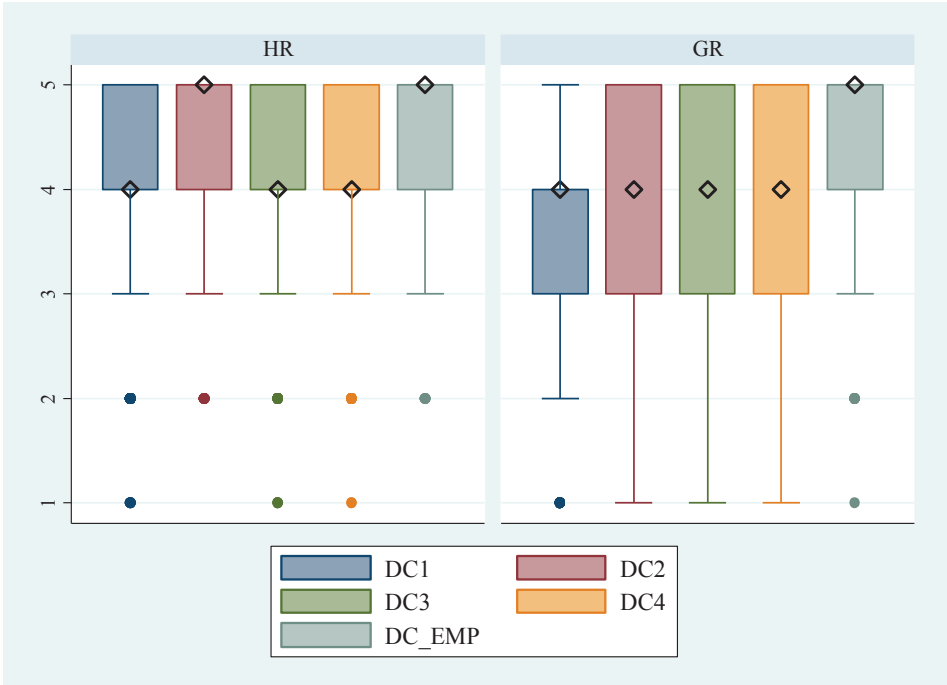
Note: DC1-Information and data literacy; DC2-Communication and collaboration; DC3-Digital content creation; DC4-Problem solving; DC_EMP-Importance of DC to the employers

Source: Authors

We can see that students from both countries reported high scores for their digital competence, and they highly value the expectations of the employers. The graphical comparison of Croatian and Greek students in terms of digital competence and its importance is shown in Graph 1.

When comparing the components of digital competence (DC1-DC4) among Croatian students, there seems to be some difference, but it is not clear if the difference is significant. In order to determine it, the Friedman test was performed. It was found that the difference was significant ($\chi^2(3) = 243.850$, $p < 0.001$). Post-hoc analysis using Nemenyi-Wilcoxon-Wilcox all-pairs test identified that the communication and collaboration component (DC2) is different at the level of significance $\alpha = 0.01$ in comparison to other components of digital competence: information and data literacy (DC1), digital content creation (DC3) and problem solving (DC4) (Table 4). The same case is with the Greek students. The Friedman test revealed that there is significant difference among the components of digital competence ($\chi^2(3) = 34.082$, $p < 0.001$). The Nemenyi-Wilcoxon-Wilcox all-pairs test used for post-hoc analysis found that, again, the communication and collaboration component (DC2) is the variable that significantly differs at the level $\alpha = 0.01$ from the other variables: information and data literacy (DC1), digital content creation (DC3) and problem solving (DC4) (Table 4).

Graph 1: Comparison of digital competence and its perceived importance among Croatian and Greek students



Note: DC1-Information and data literacy; DC2-Communication and collaboration; DC3-Digital content creation; DC4-Problem solving; DC_EMP-Importance of DC to the employers

Source: Authors

Table 4: P-values of the Nemenyi-Wilcoxon-Wilcox all-pairs test of components of digital competence in Croatian and Greek students

Competence	HR			GR		
	DC1	DC2	DC3	DC1	DC2	DC3
DC2	<0.001***			0.002***		
DC3	0.817	<0.001***		1.000	0.003***	
DC4	0.352	<0.001***	0.868	0.996	0.004***	0.999

Notes: 1) DC1-Information and data literacy; DC2-Communication and collaboration; DC3-Digital content creation; DC4-Problem solving; DC_EMP-Importance of DC to the employers

2) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: Authors

The students' perception of their digital competence (DC1-DC4) was compared with the perception of the importance of digital competence to the employers, i.e. the perception of labour market relevance (DC_EMP). In order to achieve this, the Wilcoxon signed-rank test was used, for Croatian and Greek students separately. The results show that almost all components of digital competence of the students in Croatia and students in Greece are different than their perception of the importance in the labour market, at the level of significance $\alpha = 0.01$ (Table 5). An exception is the communication and collaboration component (DC2) of Croatian students, which is not different even at the level of significance $\alpha = 0.1$, followed by their perception of the importance of digital competence to the employers. It can be observed from Table 1 that students generally value labour market importance (DC_EMP) more than they value their competence (DC1-DC4).

Table 5: Results of the Wilcoxon signed-rank test comparison of perceptions of digital competence and labour market relevance in Croatian and Greek students

Competence	HR		GR	
	Z	p	Z	p
DC1	-8.989***	<0.001	-7.842***	<0.001
DC2	-0.321	0.748	-5.394***	<0.001
DC3	-9.905***	<0.001	-7.479***	<0.001
DC4	-10.189***	<0.001	-7.835***	<0.001

Notes: 1) DC1-Information and data literacy; DC2-Communication and collaboration; DC3-Digital content creation; DC4-Problem solving; DC_EMP-Importance of DC to the employers

2) Perception of labour market relevance: variable of DC_EMP-Importance of digital competence to the employers

3) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: Authors

The following is a between analysis, i.e. a comparison of the students from Croatia and Greece. If we look at Graph 1 in regards to the distribution of Croatian and Greek students' answers, we can see that there is a difference in the assessment of digital literacy between the students from the two countries. However, when we look at what the students think about the employers' evaluation of importance of digital competence, it is not so easy to interpret the graph and conclude whether or not there is a significant difference. In order to better understand the difference between Croatian and Greek students in

terms of digital literacy, we conducted two numerical tests: the Mann-Whitney test and the Two-Sample Kolmogorov-Smirnov test. The results of the Mann-Whitney test are presented in Table 6, while the results of the Two-Sample Kolmogorov-Smirnov test are presented in Table 7.

Table 6: Results of the Mann-Whitney test and ranks of Croatian and Greek students' responses in regard to digital competence

Competence	Rank		Mann-Whitney U	Wilcoxon W	Z	p
	HR	GR				
DC1	479.66	350.50	53930.0***	80265.000	-6.915	<0.001
DC2	484.26	335.39	50469.0***	76804.000	-8.545	<0.001
DC3	473.05	364.17	57059.0***	83394.000	-5.829	<0.001
DC4	474.44	365.61	57390.5***	83725.500	-5.810	<0.001
DC_EMP	438.15	396.61	64488.5**	90823.500	-2.562	0.010

Notes: 1) DC1-Information and data literacy; DC2-Communication and collaboration; DC3-Digital content creation; DC4-Problem solving; DC_EMP-Importance of DC to the employers

2) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: Authors

The results of the Mann-Whitney test show that the students' assessment of their digital competence differs significantly in all assessed components at the significance level $\alpha = 0.01$. The students from Croatia and Greece rated the importance of digital competence for employers differently, at the significance level $\alpha = 0.05$. Table 7 shows the results of the Two-Sample Kolmogorov-Smirnov test.

Table 7: Results of the Two-Sample Kolmogorov-Smirnov test of Croatian and Greek students' responses in regard to digital competence

Competence	Most Extreme Differences			Kolmogorov-Smirnov Z	p
	Absolute	Positive	Negative		
DC1	0.233	0.000	-0.233	3.039***	<0.001
DC2	0.267	0.000	-0.267	3.482***	<0.001
DC3	0.221	0.000	-0.221	2.879***	<0.001
DC4	0.219	0.000	-0.219	2.853***	<0.001
DC_EMP	0.079	0.000	-0.079	1.029	0.241

Notes: 1) DC1-Information and data literacy; DC2-Communication and collaboration; DC3-Digital content creation; DC4-Problem solving; DC_EMP-Importance of DC to the employers

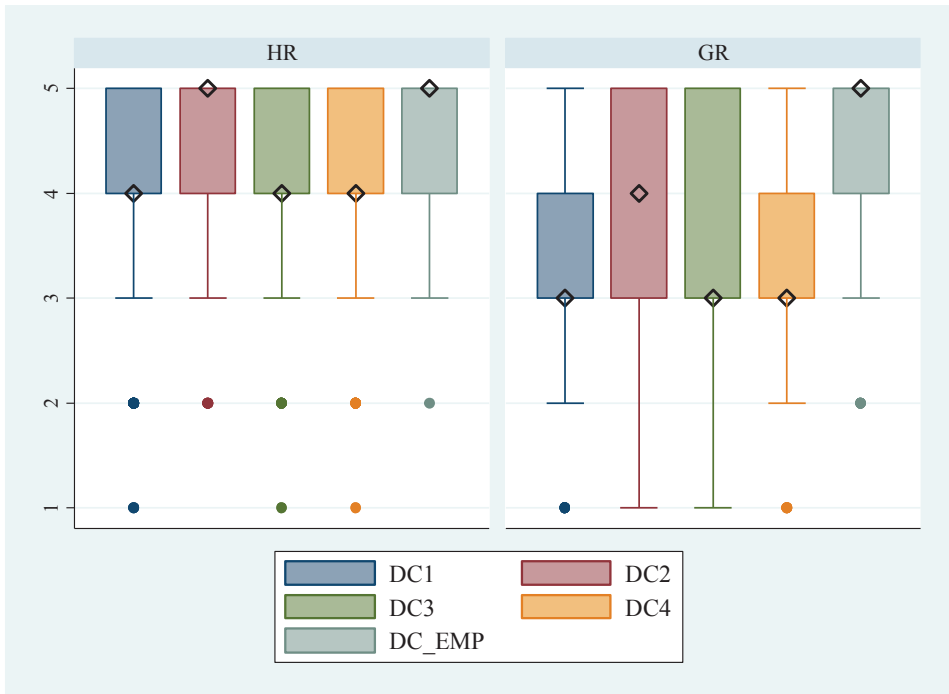
2) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: Authors

The results of the Two-Sample Kolmogorov-Smirnov test are consistent with the results of the Mann-Whitney test for the students' ratings of their digital competence, but not for their perception of employers' ratings of the importance of digital competence. There is a significant difference at the $\alpha = 0.01$ significance level for digital competence between Croatian and Greek students, but there is no significant difference in the perception of the importance of digital competence to employers, even at the $\alpha = 0.10$ significance level.

Further analysis focused on the question of whether the difference is present among all students or whether the difference is the result of the differences among female students or among male students. To this end, separate comparisons were made among the female students in Croatia and Greece, and the male students in Croatia and Greece. First, we compared the Croatian and Greek female students. The results of the graphical comparison are shown in Graph 2.

Graph 2: Comparison of digital competence and its perceived importance among Croatian and Greek female students



Note: DC1-Information and data literacy; DC2-Communication and collaboration; DC3-Digital content creation; DC4-Problem solving; DC_EMP-Importance of DC to employers

Source: Authors

As with the overall population of students from Croatia and Greece, there are clear differences in the components of digital competence rating among female students, but the extent of the difference in perceived employer expectations is not as clear. The Mann-Whitney test in Table 8 and the Two-Sample Kolmogorov-Smirnov test in Table 9 help to better understand the results.

Table 8: Results of the Mann-Whitney test and ranks of Croatian and Greek female students' responses in regard to digital competence

Competence	Rank		Mann-Whitney U	Wilcoxon W	Z	p
	HR	GR				
DC1	351.22	241.03	24738.0***	35913.00	-6.618	<0.001
DC2	352.29	233.42	23604.5***	34779.500	-7.697	<0.001
DC3	347.50	245.46	25398.0***	36573.000	-6.170	<0.001
DC4	347.51	251.50	26298.0***	37473.000	-5.772	<0.001
DC_EMP	320.61	276.53	30027.5***	41202.500	-3.170	0.002

Notes: 1) DC1-Information and data literacy; DC2-Communication and collaboration; DC3-Digital content creation; DC4-Problem solving; DC_EMP-Importance of DC to the employers

2) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: Authors

We can see that the Mann-Whitney test expresses the difference between Croatian and Greek female students as significant at the $\alpha = 0.001$ level of significance for all assessed components of digital literacy, as well as for their perceived importance to employers.

Table 9: Results of the Two-Sample Kolmogorov-Smirnov test of Croatian and Greek female students' responses in regard to digital competence

Competence	Most Extreme Differences			Kolmogorov-Smirnov Z	p
	Absolute	Positive	Negative		
DC1	0.278	0.000	-0.278	2.983***	<0.001
DC2	0.294	0.000	-0.294	3.150***	<0.001
DC3	0.302	0.000	-0.302	3.233***	<0.001
DC4	0.260	0.000	-0.260	2.785***	<0.001
DC_EMP	0.118	0.000	-0.118	1.258*	0.085

Notes: 1) DC1-Information and data literacy; DC2-Communication and collaboration; DC3-Digital content creation; DC4-Problem solving; DC_EMP-Importance of DC to the employers

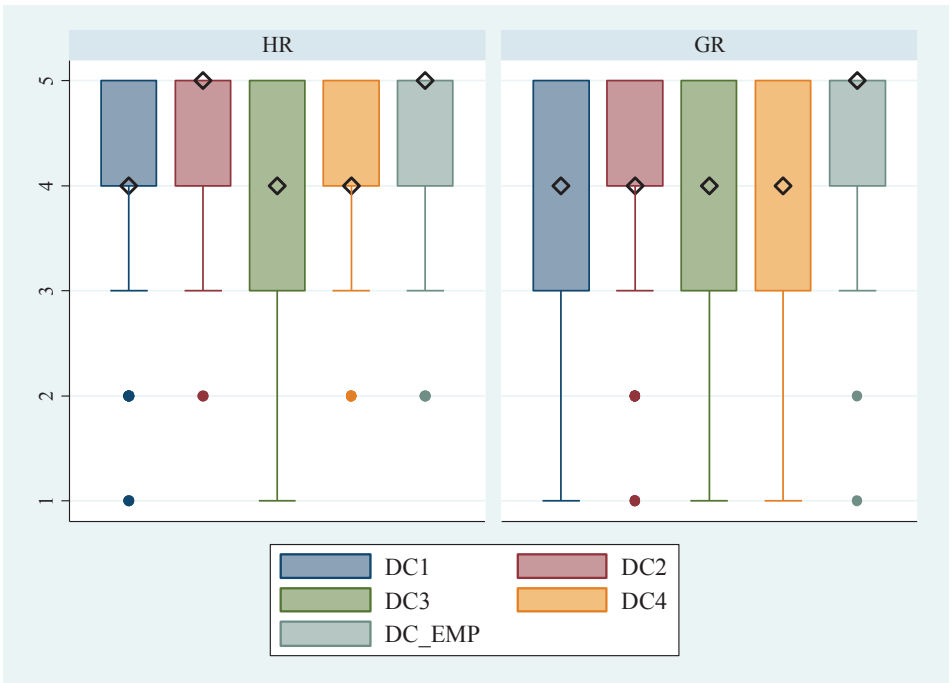
2) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: Authors

As with the total populations, the results of the Two-Sample Kolmogorov test for female students are similar to the results of the Mann-Whitney test in terms of self-assessed digital competence, but there is a difference in terms of the assessment of employers' perceptions. The difference between Croatian and Greek female students in terms of their digital competence is significant at the $\alpha = 0.01$ level of significance, while the difference in the perception of employers' expectations is significant, but to a lesser extent, i.e. at the $\alpha = 0.10$ level.

Finally, a comparison was made between male students in Croatia and Greece. The results of the graphical comparison are shown in Graph 3.

*Graph 3: Distribution of digital skills and their perceived importance among Croatian and Greek **male** students*



Note: DC1-Information and data literacy; DC2-Communication and collaboration; DC3-Digital content creation; DC4-Problem solving; DC_EMP-Importance of DC to employers

Source: Authors

If we look at the charts, we can see a mixed pattern. It seems as if there is an obvious difference between Croatian and Greek male students for some variables, while this is not the case for other variables. Numerical tests that help in the analysis are shown in Table 10 with the results of the Mann-Whitney test, and in Table 11 with the results of the Two-Sample Kolmogorov-Smirnov test.

Table 10: Results of the Mann-Whitney test and ranks of Croatian and Greek male students' responses in regard to digital competence

Competence	Rank		Mann-Whitney U	Wilcoxon W	Z	p
	HR	GR				
DC1	129.07	101.98	4918.0***	8158.000	-3.057	0.002
DC2	131.86	97.79	4583.0***	7823.000	-4.062	0.000
DC3	124.67	112.16	5732.5	8972.500	-1.386	0.166
DC4	126.84	107.83	5386.0**	8626.000	-2.115	0.034
DC_EMP	114.77	119.78	5817.5	17445.500	-0.601	0.548

Notes: 1) DC1-Information and data literacy; DC2-Communication and collaboration; DC3-Digital content creation; DC4-Problem solving; DC_EMP-Importance of DC to the employers

2) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: Authors

The differences between Croatian and Greek male students are partially significant when it comes to self-assessment, but not significant in terms of the perception of employers, according to the Mann-Whitney test.

Table 11: Results of the Two-Sample Kolmogorov-Smirnov test of Croatian and Greek male students' responses in regard to digital competence

Competence	Most Extreme Differences			Kolmogorov-Smirnov Z	p
	Absolute	Positive	Negative		
DC1	0.168	0.000	-0.168	1.224*	0.100
DC2	0.250	0.000	-0.250	1.826***	0.003
DC3	0.088	0.000	-0.088	0.639	0.809
DC4	0.150	0.000	-0.150	1.095	0.181
DC_EMP	0.042	0.042	-0.013	0.305	1.000

Notes: 1) DC1-Information and data literacy; DC2-Communication and collaboration; DC3-Digital content creation; DC4-Problem solving; DC_EMP-Importance of DC to the employers

2) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: Authors

The Kolmogorov-Smirnov test with two samples provides similar results. The self-assessment of digital competence between Croatian and Greek male students is significant for some components, but not for all. There are no significant differences in the perception of the importance of digital competence to the employer. Both tests show that communication and collaboration is the component where the difference between male students in Croatia and Greece is most expressed. For the information and data literacy component, there is a significant difference, but the tests do not agree on the magnitude of the difference, while for the problem-solving component, there is no agreement on whether the difference between the male students from Croatia and Greece is significant. Digital content creation is the component that does not differ significantly between Croatian and Greek male students, as evident in both tests.

CONCLUSION

In conclusion, this study has systematically demonstrated the differences in self-assessed digital competencies among economics and business administration students from Croatian and Greek universities. The empirical data collected from the survey using the structured questionnaires bring to light a significant difference between these two groups, with Croatian students consistently appraising their capabilities higher than their Greek counterparts across all measured variables of digital literacy. The contrast of self-assessed results is highly underlined in the component of communication and collaboration competencies, which are essential in the context of the digital economy. The outcome gap in the comparison of the results underscores the pronounced impact of educational structures and cultural frameworks on the development of digital competencies, and how students perceive these skills. The results of the study could potentially be influenced by the higher integration of digital literacy within Croatian curricula as opposed to the constraints faced by Greek students, stemming from a lower integration of digital competencies in the curricula due to less advanced technological infrastructures and educational resources. The results are consistent with the Digital Skills Indicator (DSI) from 2023, reflecting the Digital Competence Framework 2.0. When comparing the results from the DSI 2023 regarding the share of people whose digital skills are above the basic level, Croatia is ranked better than Greece. Croatia outperformed in the cluster of “individuals aged 25-34” with a score of 47.4% versus the 38.7% EU27 average. However, in the cluster of “all individuals”, Croatia achieved the result of 25.0%, while the EU27 average is 27.1%. Greece is below

Croatia and the EU27 average in both clusters, with scores for “individuals aged 25-34” amounting to 35.1%, and for “all individuals” 20.0% (The European Centre for the Development of Vocational Training CEDEFOP, 2025). Additionally, the results from the Digital Economy and Society Index (DESI 2022) confirm the higher position of Croatia in regard to the human capital and integration of digital technologies in educational systems when compared to Greece. In order to overcome these shortcomings in Greece and to enhance the position of Croatian digital competencies, higher education institutions (HEIs) could consider introducing additional mandatory digital courses into all economics and business programs, increasing collaboration with the industry through workshops, as well as mentoring programs. The government should strengthen the financial investments in improving digital infrastructure.

In addition to the above, HEIs could introduce micro-qualification programs in cooperation with the technological sector (Google, Microsoft, IBM etc). An integration of students in real case studies that the industry would provide to the HEIs and students would help stimulate and develop ideas and solutions. This includes the development of new interdisciplinary programs that would include embedding up-to-date technological novelties such as AI and blockchain into the courses of economics and business programs. They could incorporate teaching approaches and methodologies introducing gamification and virtual reality as a new way of learning. Beside the additional financial investments in upgrading the hardware, the government could simplify the procedure of starting new programs, as well as upgrading the existing ones thus enhancing the time required for administrative processes in terms of consents for the new programs. Through joint and coordinated efforts, HEIs and governments could contribute to reducing the digital competencies gap and increasing the students’ readiness for the demands of the digital economy and the labour market expectations.

All of the stated differences not only influence the self-perceived competencies, but also shape the students’ perceptions regarding the valuation of these competencies by potential employers. The findings of this study support the need for an analytical reassessment and repositioning of digital literacy programs, as well as an integration of digital competencies within all programs and classes within higher education institutions in both countries. Such a shift in the paradigm is essential to ensure the digital competence standpoints, not only to meet but also to exceed the progressing demands of the global job market, and in so doing enhance both the employability and digital fluency of the future workforce.

This study and analysis are not without limitations. Although the sample size is significant and considerable, it is limited only to the economics and

business administration students from only two universities, one in Croatia and one in Greece. This limit impacts the findings, which is highlighted in the context of other disciplines or educational contexts within these countries, let alone of other institutions and programs in the observed countries. In addition to this limitation, the study was conducted in only one university in each country, and some time had passed between them. The limitation is also that we do not know the high school background of the students. It is unquestionable that future studies could benefit from a broader sample that would include multiple institutions and academic disciplines so as to provide a more all-inclusive understanding of digital competencies across different educational surroundings. This is a cross-sectional study, which means it captures only a snapshot in time. The dynamic nature of education and the rapid evolution of technology necessitates longitudinal research in order to track the changes over time and adjust the educational strategies accordingly. Lastly, the study does not account for the specific content of digital competencies within the programs or the quality of the technological infrastructure available to students. These factors can significantly affect the development of digital skills and may contribute to the disparities observed between the Croatian and Greek students. Future research should consider these qualitative aspects in order to better understand the specific elements that contribute to effective digital education.

For the policymakers and management in academic institutions, the conclusions from this study should serve as a foothold for reshaping the programs and devising targeted educational interventions that will bridge the existing position to the desired place. Such initiatives should be specifically tailor-made to address deficits in digital education and infrastructure within each program. By doing so, a more competent and digitally proficient student population would be developed. Suggestions for further investigations could encompass longitudinal studies, supplementing the effects of suggested educational interventions in the plans, as well as an expansion of the study to encompass a wider array of disciplines and institutions. This would enrich our understanding of digital competence development at the higher education level. All this would result in contributing to more profound effective educational strategies responsive to the rapid technological advances that are characterizing the digital age that we live in, as well upgrading the students' employability. Additionally, future research could also incorporate a qualitative analysis of the content of study programs to pinpoint the factors of digital competencies' development. This could potentially result in more balance, and would show the nuanced elements that are most conducive to the successful development of digital competencies, thereby providing a more holistic view of the pathways to digital exposure in diverse educational landscapes.

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MOTHERS IN THE DIGITAL ECONOMY: THE IMPACT OF SOCIAL MEDIA INFLUENCERS ON THE CONSUMPTION BEHAVIOR OF MOTHERS

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The digital revolution, characterized by fast-paced changes and wide-spread adoption of digital technologies, has altered the consumers' expectations and behavior in the economies over the last few decades. The growing popularity of social media offers numerous opportunities for companies to communicate with their target market and position their brands in the digital economy. Social media nowadays serve as platforms not only for sharing information, but also for gaining knowledge about abundant products and services present in the marketplace. These changes have led to the emergence of social media influencers who are reviewing and endorsing many products and services, and exerting significant potential for companies navigating the digital era. Although the impact of mostly Instagram influencers on their followers has been studied recently, limited academic studies have investigated the impact of social media influencers on the consumption behavior of specific market segments. The traditional roles of family members have evolved, with mothers today representing a powerful economic force driving household purchases. Drawing on the principles of the social exchange theory and the social cognitive theory, this study aims to fill the research gap by examining a specific market segment, mothers as consumers, and the impact of social media influencers on the consumption behavior of mothers in Croatia. An exploratory study was designed using a quantitative research method, with a structured questionnaire distributed via social media groups and e-mail

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among a convenience sample. Along with examining the demographics, the questionnaire investigates the mothers' perception of social media influencers, their perceived trust in the information provided by influencers, usefulness of influencers' reviews, and frequency of purchases based on influencers' reviews. After discussing the identified gaps and limitations of this study, suggestions for future research will be presented. The results of this study will have implications for academics and professionals interested in consumption, market segmentation, and social media who wish to utilize the advantages of the new platforms in the digital era.

Keywords: *Social media influencers, consumption behavior, mothers, digital economy*

JEL classification: *D1, D8, D9*

INTRODUCTION

The digital revolution has significantly reshaped the way individuals access information, make purchasing decisions, and interact with different companies and their brands. Social media platforms emerged in this transformation and now serve not only as channels for personal connection, but also as dynamic marketplaces where businesses and consumers engage. These platforms enable companies to connect directly with their target audiences, thus redefining traditional advertising models.

Understanding the role of influencers in shaping consumption behavior is critical to businesses employing them, especially within specific demographic segments. Mothers today represent a particularly educated, independent and economically strong segment for such analyses. Traditionally viewed as central to household decision-making, mothers today represent a strong economic force that serves as the main driver of the majority of household spending. In Croatia, this demographic has evolved as well, demonstrating the same trend.

This research analyzed the role of social media influencers in shaping the consumption behaviors of mothers in the digital era. The mothers' perception of influencers, the trust in their reviews, the perceived usefulness of the reviews and the frequency of purchases driven by influencers' published content were investigated. The quantitative research method, i.e. a structured questionnaire, was employed for this study, with data collected through social media platforms and e-mails from mothers in Croatia who have at least one child aged eight years or younger.

The findings indicate a moderate influence of influencers on the consumption behavior of mothers. While mothers follow influencers on social media and are interested in different types of published content, many of them express skepticism toward the influencers' intentions and authenticity. On the other hand, others acknowledge the usefulness of the influencers' reviews. Specifically, younger mothers exhibit a greater receptiveness to influencers and their content compared to mothers of an older age. The results highlight the need for personalized marketing strategies created by companies in the new, extremely dynamic and digitalized business environment. The results have both practical and theoretical implications for academics and professionals interested in consumption, market segmentation, and social media platforms.

LITERATURE REVIEW

DIGITAL ECONOMY AND SOCIAL MEDIA PLATFORMS

Fast-paced changes and widespread adoption of digital technologies have altered consumers' expectations and behavior in the economies over the last few decades. The growing popularity of social media offers numerous opportunities for companies to communicate with their target market and position their brands in the digital economy. Social media nowadays serve as platforms not only for sharing information, but also for gaining knowledge about abundant products and services present in the marketplace.

Chen (2020) explains that platforms today serve as intermediaries for market transactions and the interaction between consumers and producers. According to the author, platforms and platform-enabled goods and services are of growing importance in the digital economy. They allow consumers to decrease their search costs on the Internet, which has become a vast marketplace. With so many choices available, platforms allow consumers to gain information about the greatly expanded market offers. Firms, on the other hand, equipped with digital technologies, are able to collect valuable information about consumer preferences and to use that knowledge in their business activities (Chen, 2020).

Iastremska et al. (2023) argue that businesses that use social media platforms have the ability to directly communicate with the target market and by doing that, they can track their reactions in real time. When social media users share information about products and services, they produce significant benefits for the companies, helping them to increase the activity of the target mar-

ket, both online and offline. The authors (2023) point out that although there has been a significant increase in interest in social media marketing, there is still a need for further investigation into some aspects of this topic, such as the role of social media influencers in marketing.

SOCIAL MEDIA INFLUENCERS

Social media influences in today's world can be defined as “new idols who owe their fame to social media” (Ruiz-Gomez, 2019:11), with many differentiating terms that are used to explain the forms of fame on platforms, such as micro-celebrity, instafamous, internet famous, etc. They “act as modern day opinion leaders who work in a digital environment to provide information and influence their followers” (Zia, Zahra, Hayat, 2021:8). As defined by some other authors, they are shapers of public opinion who persuade their audience through “the conscientious calibration of personae on social media, as supported by ‘physical’ space interactions with their followers in the flesh to sustain their accessibility, believability, emulate-ability, and intimacy – in other words, their ‘relatability’ (Abidin, 2015; Abidin & Ots, 2016), and for those who have achieved recognition – the media, practitioners and general public will use the term social media influencer (Ruiz-Gomez, 2019).

In their research, authors Mendoza-Moreno and Turriate-Guzman (2022) documented the trends observed in the studies on the impact of social media influencers on consumer behaviors. Rivera (2020) highlighted that messages delivered by influencers tend to receive greater acceptance compared to those from mass media and traditional advertising because they target a specific audience. In essence, influencers communicate with a group that shares common tastes, lifestyles, and even ideologies. Similarly, a study by Cueva et al. (2020), focusing on a sample of millennials, identified a direct link between influencer marketing and the purchasing behavior of millennial consumers (Rivera, 2020., Cueva et al., 2020., as cited in Mendoza-Moreno and Turriate-Guzman, 2022).

At the same time, through personal branding and regular interactions influencers are able to monetize the specific relationships with the followers they gather over time, by creating content sponsored by consumer brands (Abidin, 2016; Suuronen et al., 2022, as cited in Pöyry and Reinikainen, 2024). Self-branding, or personal branding “involves individuals developing a distinctive public image for commercial gain and/or cultural capital (...) and central to self-branding is the idea that, just like commercially branded products, indi-

viduals benefit from having a unique selling point, or a public identity that is singularly charismatic and responsive to the needs and interests of target audiences” (Khamis, 2017:1).

That is one of the main reasons why researchers view social media influencers as some kind of commercial actors, because of their direct involvement in sponsored collaborations, endorsement brand agreements, and influencer marketing campaigns. These practices are widespread, as followers are often keen to emulate influencers’ lifestyles, buy the products and services they promote, and rely on their advice and/or recommendations (Pöyry et al., 2019; Lueck, 2015). In addition, as it was concluded by Ashraf et al. (2023), they can engage followers in two-way communication, effectively shaping their intentions in favor of the brand.

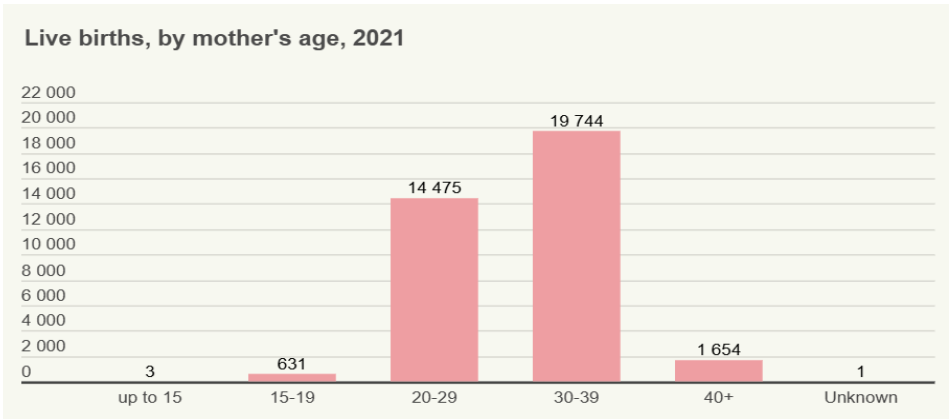
According to The Influencer Marketing Benchmark Report 2024 issued by the Influencer Marketing Hub, when influencer marketing began gaining traction in 2017, only 37% of respondents planned to allocate a budget for it, while today that figure has surged to an impressive 85.8%, highlighting the maturation of influencer marketing. A consumer research study from 2023 (Impact, 2023) explored the trust that social media users aged 18 and older have in the influencers they follow, and the study identified some of the key factors that are driving consumers to act on influencer recommendations. While product demonstrations and reviews ranked the highest (35%), significant discounts, offers and promotions were also powerful motivators, with 30% of respondents stating they would purchase a product if an influencer provided a promo code for a substantial discount. Interestingly, however, consumers did not report following influencers specifically for the discounts, deals, or promotions they provide. A 2024 study by Sprout Social revealed that influencers significantly boost interest in industries such as food, beauty, fitness, and gaming. The study also highlighted a strong level of trust in influencers among Millennials and Gen Z, who are more inclined to engage with content that resonates with their personal values and lifestyles. Additionally, almost half of the respondents reported making daily, weekly, or monthly purchases influenced by influencer posts, with one third of them expressing greater trust in influencers compared to just six months prior. Millennials and Gen Z, often classified as “frequent buyers” due to their daily or weekly purchasing habits, place greater emphasis on an influencer’s posting frequency and follower count. In contrast, older consumers, who tend to make purchases less frequently, value authenticity and alignment with their personal values more highly. With regard to the purchases of one specific group - females, Zia et al. (2021) examined the influence of social media influencers on the purchasing decisions of women, and their find-

ings revealed that consuming content from Instagram beauty influencers significantly affects followers’ purchasing decisions, including their tendency to make impulse purchases.

MOTHERS AS CONSUMERS

The traditional roles of family members have evolved in the recent decades. On average, today women become mothers at an older age than in the past. The Croatian Bureau of Statistics (2021) reports that, if taking into consideration the total number of births, the average age of mothers at the birth of their first-born child is 31, which is significantly higher than half a decade ago when mothers were giving birth to their first child at almost 23 years old.

Graph 1: Live births, by mother’s age, Croatia, 2021



Source: Croatian Bureau of Statistics, www.dzs.gov.hr

Graph 1 shows the statistics on motherhood in Croatia according to the last population census in 2021. The majority of women in Croatia become mothers in their thirties, followed by mothers in their twenties, and then mothers in their forties, according to the Croatian Bureau of Statistics. In addition, the same report explains that 87.9% of mothers of the children born in 2021 were employed or looking for their first employment, and only 5.7% of mothers were dependent (0.4% of mothers only have personal income in the form of social benefits, rental income or pensions, while for the remaining 6% of mothers the information is unknown). With these recent changes in demographics, the

mothers today have become a powerful economic force that drives household purchases.

Mothers today are often referred to as “the CEO of family spending”, and some of the world economies report that the stereotypes of mothers purchasing only baby products are outdated, especially with Gen Z mothers who are introducing new perspectives and shopping habits (Avenue7Media, 2024). Carter (2024) emphasizes that women today represent a tremendous purchasing power, and are in fact, in control of most of the global spending.

Several academic studies in Croatia (Torbarina, Jelenc, Brkljacic, 2020; Lovric, Benezic, Ruzic, 2022; Tkalec et al., 2024) have explored the impact of different social media influencers and their behavior in the digital economy. Although the impact of mostly Instagram influencers on their followers has recently been studied, limited academic studies have investigated the impact of social media influencers on the consumption behavior of specific market segments. This study, drawing on the principles of social exchange theory and social cognitive theory, aims to fill the research gap by examining a specific market segment, i.e. mothers as consumers, and the impact of social media influencers on the consumption behavior of mothers in Croatia.

The key framework for analyzing social interactions and structure is social exchange theory, where social relationships are interpreted as exchanges of costs and benefits, while social structures are seen as networks of interconnected relationships. In the context of social media influencers, the followers interact with content because of different benefits or rewards: discovering new products, finding inspiration, or feeling a sense of connection. In return, as mentioned, influencers can gain benefits such as greater visibility, sponsorship opportunities, and enhanced social capital. This mutual exchange creates a cycle of value, where influencers can shape purchase decisions by delivering content that resonates with and rewards their audience.

At the same time, the core principle of social cognitive theory is that learning takes place within some social context through observation, imitation and modeling. In the context of this study, mothers observe influencers using or endorsing different products, which may model their overall behavior, particularly when it aligns with their own values, lifestyles and goals. In the end, followers can become more inclined to adopt similar behavior or specifically, to purchase products recommended by the influencer.

The following section discusses the research methodology and research questions posed by the authors with the goal of investigating the mothers' perception of social media influencers, perceived trust in the information provided by influencers, usefulness of influencers' reviews, and frequency of the purchases based on influencers' reviews.

RESEARCH METHODOLOGY

RESEARCH OBJECTIVE AND QUESTIONS

The research aim was to investigate the impact of social media influencers on the consumption behavior of mothers by first examining the mothers' perception of social media influencers, perceived trust in the information provided by influencers, usefulness of influencers' reviews, and frequency of the purchases based on influencers' reviews. The following research questions were formed:

RQ1: What is the mothers' overall perception of influencers?

RQ2: To what extent do mothers trust influencers?

RQ3: What is the mothers' perceived usefulness of influencers' reviews?

RQ4: How frequently do mothers buy products or services recommended by influencers?

RQ5: What is the impact of social media influencers on the consumption behavior of mothers?

RESEARCH SAMPLE

According to the Croatian Bureau of Statistics and their last population census, in 2021 there were 218,780 mothers with children who were eight years old or younger. The mothers of children eight years old or younger were chosen for this study because prior research shows that children over the age of eight make their own purchasing decisions (Raphael, 1993 as cited in Johns and English, 2014).

The survey was conducted via social media platforms, on a convenience sample, during the months of November and December 2024. A total of 434 mothers participated in the study, with 47 being eliminated from the sample because they stated in the elimination question that they do not follow influencers on social media. The final sample size of mothers with children eight years old or younger, who completed the survey, was 387.

RESEARCH INSTRUMENT AND STATISTICAL ANALYSIS

A quantitative research method was employed for the research, using a structured, self-administered questionnaire that consisted of 21 closed-ended questions, nine of which investigated the demographics. The pilot test was conducted among several different academics and mothers from different age groups, educational backgrounds and professions in order to check the clarity of the questions. Three questions were reformulated before the questionnaire was sent out to the participants through social media platforms. The collected responses were processed using the Statistical Package for Social Sciences (SPSS). Descriptive statistics and correlation analysis were used to interpret the results.

RESEARCH RESULTS AND DISCUSSION

Table 1 shows the demographic characteristics of the sample of mothers in Croatia who participated in the study and completed the questionnaire. Specifically, the data in the table reveals key findings in regard to age, education, marital status, employment, income, and number of children of the mothers in the sample. The sample is predominantly composed of mothers aged between 25 and 44, accounting for 95.9% of the total number, with the majority of mothers aged between 35 to 44. This indicates a relatively young population of mothers in Croatia. When it comes to the education level of the mothers in the sample, a significant majority (98.4%) of the respondents have attained at least a high school education. Furthermore, 63% hold a graduate degree, suggesting a high level of educational attainment among mothers in Croatia. A total of 91% of the mothers in the sample are married, followed by single mothers 3.9% and divorced 2.1%. Furthermore, 64.9% of them are employed, while 7.5% of the mothers are self-employed, followed by the mothers who are both employed and self-employed. The personal net income of mothers in Croatia mostly falls within the range of 1000 to 1499.99 euros per month, while 24.5% of mothers earn 1500 to 1999.99 euros per month. A total of 13.2% of the mothers report income in the range of 670 to 999.99 euros per month. These results are in accordance with the last population census of the Croatian Bureau of Statistics in 2021, that reported almost 90% of the Croatian mothers being employed, once again pointing out the fact that mothers today are in possession of their own income and that they represent a major economic force. In addition, the majority of the mothers in the sample have two children (50.6%), followed by the

mothers with one child (33.6%). Overall, the data indicates a relatively young and highly educated population of mothers in Croatia with a strong presence in the workforce, who are married, and have established families.

Table 1: Sample demographics

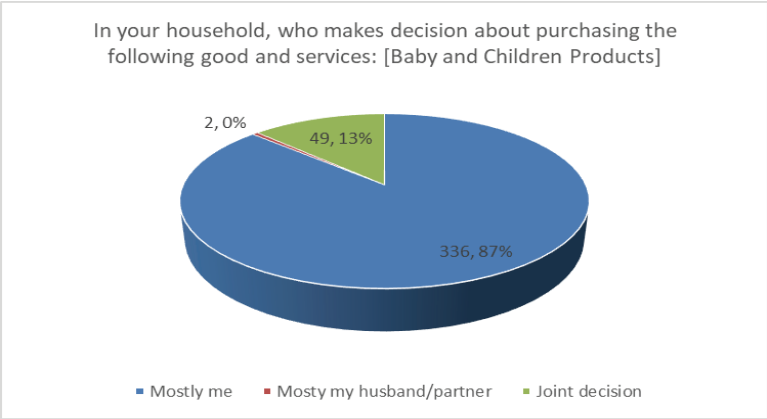
Age					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	18 - 24	6	1.6	1.6	1.6
	25 - 34	167	43.2	43.2	44.7
	35 - 44	204	52.7	52.7	97.4
	45 - 54	10	2.6	2.6	100.0
	Total	387	100.00	100.00	
Education					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	High School	82	21.2	21.2	21.2
	Undergraduate degree	55	14.2	14.2	35.4
	Graduate degree	244	63.0	63.0	98.4
	Doctoral degree	6	1.6	1.6	100.0
	Total	387	100.0	100.0	
Marital Status					
		Frequency	Percent	Valid percent	Cumulative percent
Valid	Single	15	3.9	3.9	3.9
	Married	354	91.5	91.5	95.3
	Divorced	8	2.1	2.1	97.4
	Widowed	1	.3	.3	97.7
	Other	9	2.3	2.3	100.0
	Total	387	100.0	100.0	
Employment Status					
		Frequency	Percent	Valid percent	Cumulative percent
Valid	Unemployed	16	4.1	4.1	4.1
	Employed	251	64.9	64.9	69.0
	Self-employed	29	7.5	7.5	76.5
	Employed and self-employed	24	6.2	6.2	82.7
	Maternity leave	67	17.3	17.3	100.0
	Total	387	100.0	100.0	

Personal Net Income (€)					
		Frequency	Percent	Valid percent	Cumulative percent
Valid	< 670	35	9.0	9.0	9.0
	670 – 999.99	51	13.2	13.2	22.2
	1000 – 1499.99	147	38.0	38.0	60.2
	1500 – 1999.99	95	24.5	24.5	84.8
	2000 – 2499.99	41	10.6	10.6	95.3
	> 2500	18	4.7	4.7	100.0
	Total	387	100.0	100.0	
Number of Children					
		Frequency	Percent	Valid percent	Cumulative percent
Valid	1	130	33.6	33.6	33.6
	2	196	50.6	50.6	84.2
	3	48	12.4	12.4	96.6
	4	11	2.8	2.8	99.5
	5	2	.5	.5	100.0
	Total	387	100.0	100.0	

Source: Authors

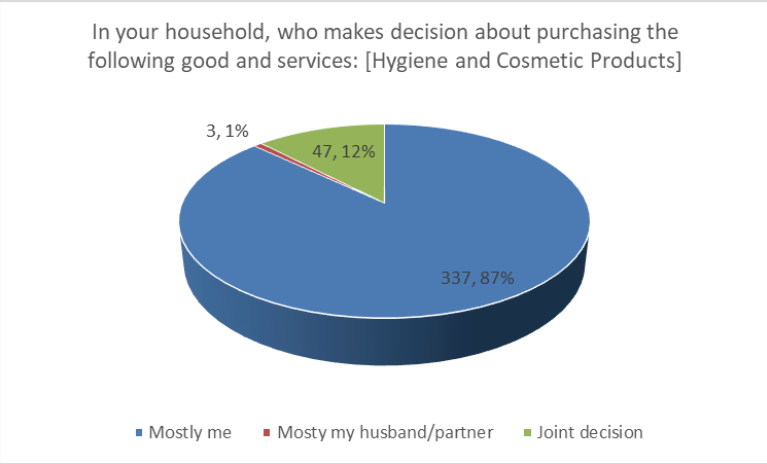
Some of the previous literature review findings indicate that mothers today make the majority of purchasing decisions in their households. Mothers are no longer in charge only of the baby products, but they drive the household purchases of different goods and services. The following graphs (2 – 6) portray the purchasing decisions of mothers in Croatia when it comes to different categories of products and services. In accordance with the previous research results, mothers in Croatia make the majority of purchasing decisions in their households when it comes to products for babies and children, hygiene and cosmetic products, clothes, shoes, home décor and cultural activities attended by the family members.

Graph 2: Purchasing decisions in the households



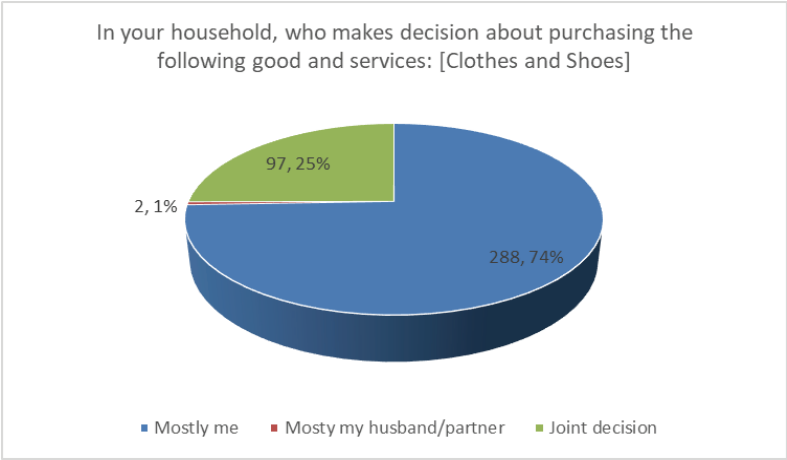
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Graph 3: Purchasing decisions in the households



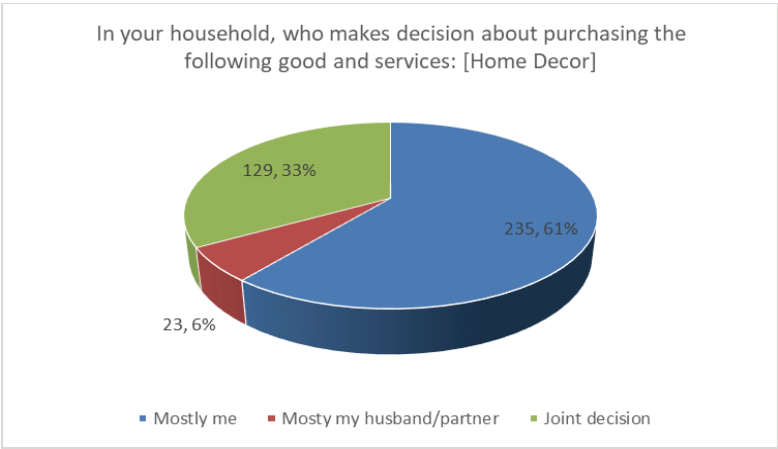
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Graph 4: Purchasing decisions in the households



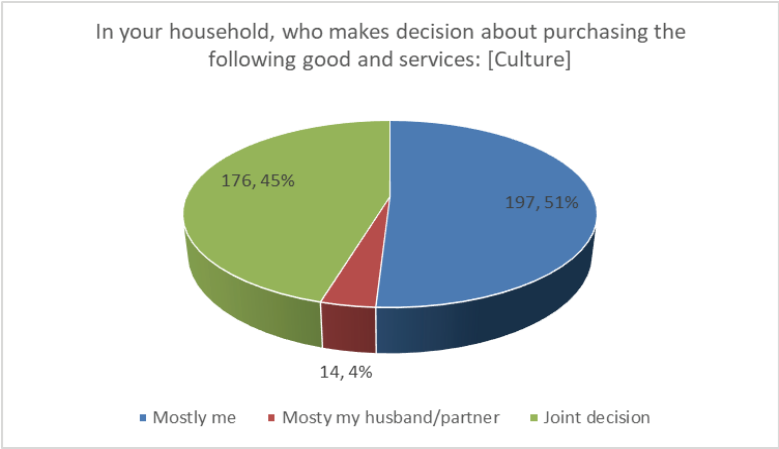
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Graph 5: Purchasing decisions in the households



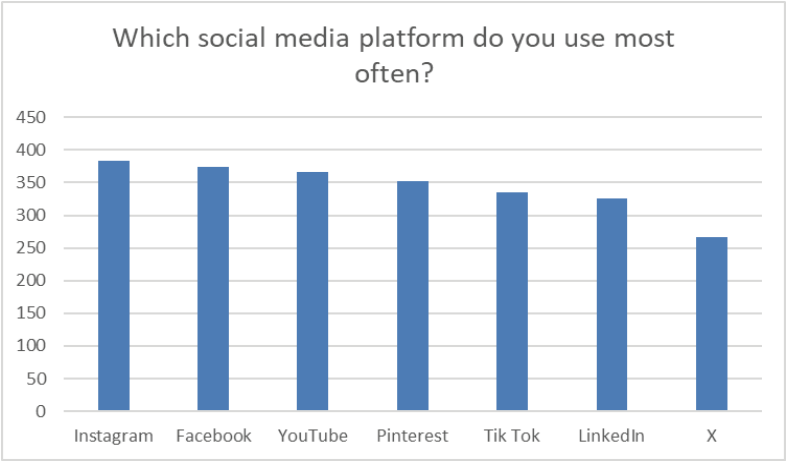
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Graph 6: Purchasing decisions in the households



Source: Authors

Graph 7: Usage of social media platforms

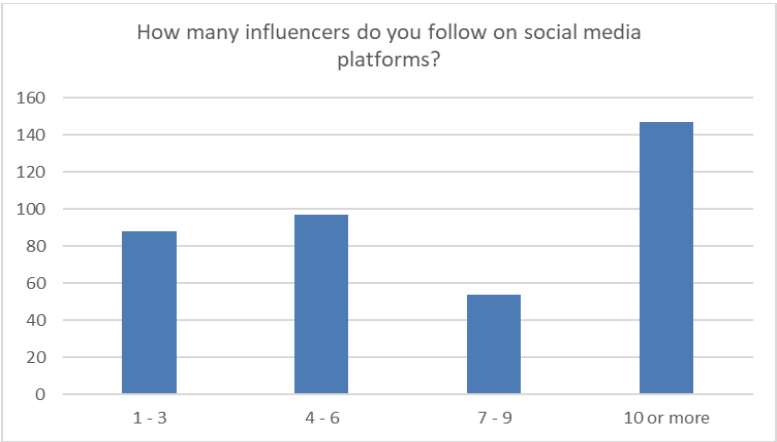


Source: Authors

Graph 7 shows the social media platforms that mothers in the sample use the most. The most popular and used platform is Instagram, followed by Facebook and YouTube, while X is the least used social media platform. The majority of mothers in Croatia follow 10 or more influencers (Graph 8), while

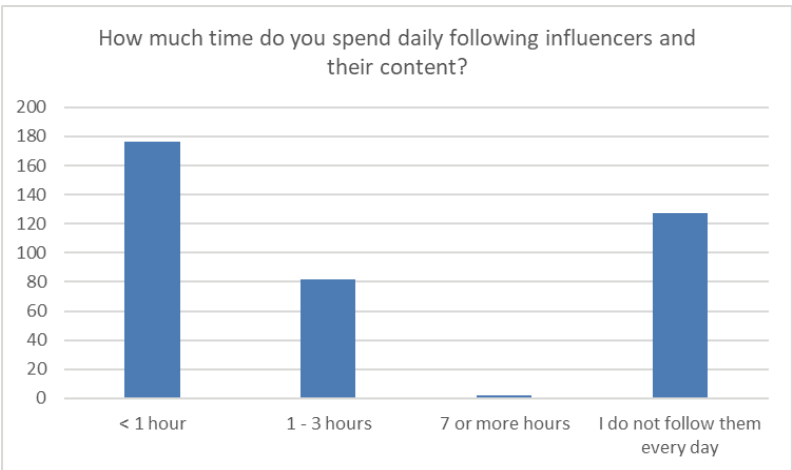
most of them spend less than an hour a day following the influencers, followed by the mothers who responded that they do not follow influencers every day (Graph 9). The influencers’ published content that is of interest to Croatian mothers is mostly related to family and motherhood topics, travel, food and home décor (Graph 10).

Graph 8: Number of influencers followed



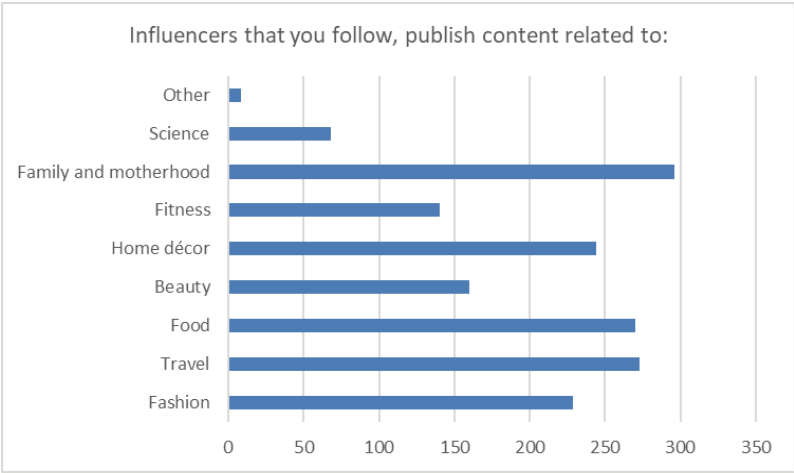
Source: Authors

Graph 9: Daily amount of time spent following influencers



Source: Authors

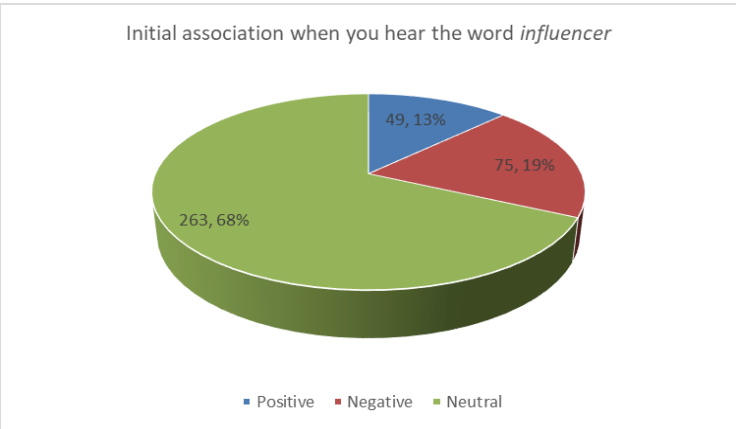
Graph 10: Content published by influencers followed



Source: Authors

The results regarding the mothers' views of influencers, trust in influencers and their reviews, and the frequency of purchases based on influencers' reviews are presented next. Graph 11 portrays that the majority (68%) of the mothers in the sample have a neutral view of influencers, followed by the mothers who have negative associations in connection to influencers (19%), while 13% of them have a positive image of social media influencers.

Graph 11: General perspective of influencers



Source: Authors

The results presented in Table 2 indicate that most of the respondents have a neutral opinion when it comes to influencers, with the majority reporting the median result of 3. Mothers hold either a neutral or negative view of the influencers' trustworthiness, perceived motivation for publishing content, and the usefulness of following them. When it comes to trust in influencers and their honesty, the statement "*I believe influencers are honest*" shows a median score of 3, indicating the mothers' neutral stance towards influencers' honesty (49.9%). A total of 41.4% of respondents expressed some level of distrust (either "Strongly Disagree" or "Disagree"), while only 8.8% (either "Agree" or "Strongly agree") indicated that they consider influencers to be honest. Similarly, when it comes to the belief that influencers indeed use the products they publish, responses were mostly neutral (median score of 3), but a significant distrust was found as 43.2% of the mothers disagreed with the statement.

When analyzing the perception of the ethical behavior of influencers and their motivations for publishing content, significant disagreement was found for the statement "*I believe influencers would not try to take advantage of their audience*" with the median score of 2. Specifically, 58.4% of the mothers either strongly disagreed or disagreed with the statement, suggesting that they believe that influencers prioritize their own interests over the customers' well-being. This opinion was further reinforced by responses to the statement "*I believe influencers think primarily about their own benefit*", where 41.1% agreed or strongly agreed. These findings emphasize the concern about influencers' ethical practices and motivations.

Despite the indicated skepticism towards influencers' honesty and ethical behavior, mothers maintained a neutral opinion on the usefulness of following influencers (median score of 3, 54.8% reported a neutral opinion, while 27.4% expressed agreement). Additionally, a notable 23.3% of the mothers expressed disbelief that following influencers brings more benefits than harm, although the majority again stated a neutral opinion. When it comes to trust in the reliability of influencers' reviews, the same median of 3 was found. However, 40.8% of the respondents expressed skepticism. Similarly, when asked if influencers provide valuable learning opportunities, responses were largely neutral (median = 3), although a quarter of the respondents (24.5%) disagreed.

Almost 50% of the mothers remained neutral when it comes to their trust in influencers with a smaller number of followers in comparison to those with a larger number of followers (median = 3). However, a small subset (20.4%) indicated greater trust in micro-influencers. These findings suggest a potential differentiation in trust between different sizes of influencers.

Table 2: Mothers' overall perception of influencers and their trust in influencers

Statement	1 - Strongly disagree	2 - Disagree	3 - Neutral	4 - Agree	5 - Strongly agree	Total (Valid %)	Median
I believe influencers are honest.	54 (14.0%)	106 (27.4%)	193 (49.9%)	28 (7.2%)	6 (1.6%)	387 (100.0%)	3
I believe influencers would not try to take advantage of their audience.	108 (27.9%)	118 (30.5%)	96 (24.8%)	32 (8.3%)	33 (8.5%)	387 (100.0%)	2
I believe influencers think primarily about their own benefit.	20 (5.2%)	55 (14.2%)	153 (39.5%)	102 (26.4%)	57 (14.7%)	387 (100.0%)	3
I believe following influencers is useful.	17 (4.4%)	52 (13.4%)	212 (54.8%)	92 (23.8%)	14 (3.6%)	387 (100.0%)	3
I believe following influencers brings more benefits than harm.	21 (5.4%)	69 (17.8%)	205 (53.0%)	72 (18.6%)	20 (5.2%)	387 (100.0%)	3
I believe in the reliability of the content of influencers' reviews.	50 (12.9%)	108 (27.9%)	185 (47.8%)	34 (8.8%)	10 (2.6%)	387 (100.0%)	3
I believe influencers really use products and services that they publish about.	54 (14.0%)	113 (29.2%)	165 (42.6%)	47 (12.1%)	8 (2.1%)	387 (100.0%)	3
I believe a lot can be learned from influencers.	32 (8.3%)	95 (24.5%)	180 (46.5%)	67 (17.3%)	13 (3.4%)	387 (100.0%)	3
I trust influencers with a smaller number of followers more than influencers with a large number of followers.	40 (10.3%)	76 (19.6%)	192 (49.6%)	47 (12.1%)	32 (8.3%)	387 (100.0%)	3

Source: Authors

The results presented in Table 3 provide insight into the mothers' perceptions of the usefulness of influencer reviews and the frequency of their impact on purchasing decisions. The majority of the mothers (63.3%) indicated that they sometimes find influencer reviews useful, while 20.2% indicated that they often find them useful. The median score equals 3 and it suggests that although published content is perceived as somewhat beneficial, it does not necessarily provide strong guidance in decision making for mothers in Croatia. When evaluating whether the published reviews save time for the mothers in their product selection, 47% of them stated "Sometimes", while 24% stated "Often" and 5.2% "Very often". However, 23.8% (combining "Never" and "Rarely") indicated that the reviews do not contribute to time efficiency. Regarding whether influencer reviews contain enough detail for the mothers to make an informed purchase decision, 45.5% of them stated "Sometimes", while 22.5% responded with "Often". A notable 28.4% of the mothers expressed skepticism and responded with "Never" or "Rarely". These results indicate that although the published content and reviews do have some depth in terms of the information needed by the mothers to make an informed purchasing decision, many mothers still do not find them sufficient.

The extent to which published influencer reviews lead to actual consumption by mothers appears to be limited. A total of 37.7% stated that they sometimes buy products based on reviews, but 44.5% of them answered rarely or never. Only 17.8% of the mothers' purchases are based on influencer reviews often or very often. These results reinforce the idea that influencers are subject to skepticism. The median score of 3 for the purchasing likelihood when discount codes are provided indicates that a significant portion of mothers remains unmoved by promotions and incentives from influencers. A total of 32.8% indicated that they sometimes make purchases using discount codes, while 23.5% indicated that they purchase with codes often or very often. However, 43.7% of the mothers rarely or never react to promotions. The slight increase in purchasing frequency when discount codes are provided suggests that price reductions only slightly enhance influencers' power.

Table 3: The perceived usefulness of influencers' reviews and frequency of mothers' purchases based on influencers' reviews

Statement	1 - Never	2 - Rarely	3 - Sometimes	4 - Often	5 - Very often	Total (Valid %)	Median
Influencer reviews are useful.	2.3% (9)	10.9% (42)	63.3% (245)	20.2% (78)	3.4% (13)	387 (100.0%)	3
Influencer reviews save time when choosing products and services.	6.2% (24)	17.6% (68)	47.0% (182)	24.0% (93)	5.2% (20)	387 (100.0%)	3
Influencer reviews provide enough details for an informed purchase decision.	5.9% (23)	22.5% (87)	45.5% (176)	22.5% (87)	3.6% (14)	387 (100.0%)	3
I purchase products/services based on influencer posts.	17.1% (66)	27.4% (106)	37.7% (146)	14.7% (57)	3.1% (12)	387 (100.0%)	3
I purchase products/services based on an influencer's posts when they offer a discount code.	23.5% (91)	20.2% (78)	32.8% (127)	17.8% (69)	5.7% (22)	387 (100.0%)	3

Source: Authors

When it comes to communicating directly with influencers, the mothers state that they almost never communicate with them and do not commonly seek out additional information about content published by influencers. However, there is an opportunity for influencers to try to encourage their followers to actively engage in communication and reach out for additional information.

Some authors explain that when it comes to trust between different parties, two-way communication can enhance it, and can influence commitment to the mutual benefit of all the parties involved (Briones et al., 2011 as cited in Johns and English, 2014). The findings of this study, which also evaluated the communication between mothers and influencers and its impact on the trust that mothers pose in influencers, are consistent with previous research. They indicate that there is a moderate to strong positive relationship between the two variables (Table 4). They highlight the importance of direct interaction and influencers' engagement with the followers, since it enhances the trustworthiness of influencers. The higher the responsiveness from social media influencers, the more likely it is that the follower will trust the influencer's opinions and recommendations.

Table 4: Correlation between communication with influencers and trust in them

			I receive the influencers' replies to my questions and/or comments posted.	The communication I have with influencers on social media platforms increases the trust I have in them.
Spearman's rho	I receive the influencers' replies to my questions and/or comments posted.	Correlation Coefficient	1.000	.590**
		Sig. (2-tailed)		.000
		N	207	202
	The communication I have with influencers on social media platforms increases the trust I have in them.	Correlation Coefficient	.590**	1.000
		Sig. (2-tailed)	.000	
		N	202	206

**. Correlation is significant at the 0.01 level (2-tailed).

Source: Authors

The results of this study also indicate that the mothers who reported positive associations with the word “influencer” present significantly higher mean scores than the “negative and neutral” mothers when it comes to the questions dealing with the overall attitude towards influencers, usefulness of their reviews and impact on the consumption behavior. The “positive” group generally perceives influencers’ reviews and posts more useful, timesaving, informative, and motivating for their purchasing decisions (with or without discount codes).

Significant age group differences were found in the study as well. The t-test results reveal that younger mothers (18 – 34 years old) record higher ratings than the mothers of an older age (35 or older) when it comes to perceived usefulness of influencers’ reviews, saving time, and overall impact on purchasing decisions. These results are consistent with the previous research about Gen Z consumers.

IMPLICATIONS AND FUTURE RESEARCH

The results of this research pose both theoretical and practical implications. In academia, this study enlarges the existing, limited literature on the impact of social media influencers on specific market segments, in this case mothers, in the Republic of Croatia. It helps broaden the understanding of the dynamics between the two groups in the digital economy. In addition, academics interested in the consumption behavior of mothers, market segmentation and social media who wish to utilize the advantages of the new platforms in the digital era, can draw on the findings of this study. Managers from various companies, interested in shaping effective marketing strategies and employing social media influencers in order to reach the targeted market segments, could also possibly use the findings to better understand the consumption behavior of mothers in Croatia and their attitudes towards influencers, and to help them make more informed business decisions.

Future research could analyze in more detail whether the mothers' perspectives differ based on different demographic characteristics or influencer category (related to the type of content they post). It would be beneficial to further explore if the mothers' perceptions differ based on the platforms where they primarily follow the influencers (Instagram, Facebook and YouTube). In depth interviews with mothers can be conducted so as to further explore the reasons why mothers follow influencers. In addition, further research around consumption habits of younger mothers (Gen Z) can be conducted. All of these studies could further expand the existing literature on the power of influencers in marketing, and help to better understand the complex business environment in today's digital economy.

CONCLUSION

The rise of digital platforms and the evolution of the digital economy have significantly transformed market interactions and consumer behavior. Social media influencers nowadays play a pivotal role in shaping purchasing decisions. The findings of this study suggest that mothers in Croatia, as a highly educated and economically independent market segment that represents a significant force behind their household purchasing decisions, follow a significant number of influencers primarily on Instagram, Facebook and YouTube. The topics they are interested in are related to family and motherhood, food, travel, home décor and fashion. Generally, they demonstrate a neutral to skeptical view of

social media influencers. However, there is a distinct variability in their views, as younger mothers relatively recognize the value in influencers' reviews, find their content useful and believe that it saves them time when choosing among the abundant products and services, as opposed to older mothers who have a more skeptical perspective of influencers. Many mothers continue to question the influencers' true intentions behind their content and indicate a level of caution in trusting their reviews. The different perspectives across age groups highlight the need for companies to tailor their business, especially marketing strategies, to different demographic groups in the rapidly changing economies of today. Two-way communication can enhance trust in influencers and in the authenticity and credibility of their content, therefore social media influencers should take this into consideration when trying to reach the target audience and persuade them to purchase different products and services. This study contributes to the relatively limited literature on influencer marketing in Croatia, expanding the existing theoretical understanding of the consumption behavior of mothers in the digital age. Future research could focus on exploring how specific factors, such as influencer category, platform choice or content, influence the mothers' overall perception and consumption behavior. Qualitative research, in-depth interviews or focus groups, could offer more specific insights into the evolving trends and dynamics across social media platforms in the digital economy.

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DIGITIZATION IN THE BUSINESS OF ACCOMMODATION AND FOOD SERVICES SECTOR / DIGITALIZACIJA U POSLOVANJU DJELATNOSTI PRUŽANJA SMJEŠTAJA TE PRIPREMI I USLUŽIVANJU HRANE U REPUBLICI HRVATSKOJ

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As a result of increasing technological advancements and numerous innovations in the field of ICT, there is a growing need for digitalization and digital transformation in business operations. The COVID-19 pandemic has had a particularly significant impact on the introduction of digitalization in business and the improvement of its current state of digitalization. It affected the entire world and caused numerous problems. However, it also became a catalyst for the adoption of new technological solutions and accelerated the introduction of numerous innovations. Consequently, customer expectations in the hospitality service sector have increasingly focused on the digitalization of the entire service. Therefore, this paper will not only define the concept and determine the importance of digital transformation in business operations but also analyze the degree of digitalization in the accommodation and food preparation and serving sectors in Croatia. These sectors are crucial for attracting new guests and retaining existing ones through visibility on social media and the adoption of innovations and new technologies such as accommodation booking apps, virtual and augmented reality, and similar tools. The research was conducted through an anonymous survey distributed via email and social media. The survey questionnaire consisted of seven groups of questions,

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categorized by two criteria: the size and type of accommodation facilities, and the region where these facilities are located. The target group of the research were owners or employees of accommodation facilities who are well acquainted with the operations of the industry being studied. A total of 106 respondents participated in the survey, and the results showed that the highest degree of digitalization in the business operations of the analyzed industry was achieved in Eastern Croatia, while Gorska Croatia exhibited the lowest level of digitalization. According to the type of accommodation, the highest degree of digitalization was achieved in hotel accommodations, while hostels exhibited the lowest degree. Respondents believe there is room for improvement in their business operations regarding digitalization; however, many highlight issues such as a lack of digital skills and the high costs associated with implementing digitalization. However, the majority of respondents are willing to invest additional funds to achieve a higher degree of digitalization in their business operations. An important issue contributing to the lower level of digitalization in business operations in the Republic of Croatia is the lack of awareness about programs and competitions available to entrepreneurs. Additionally, a significant number of accommodation providers do not participate in free training sessions that could help them acquire additional digital skills.

Keywords: digitization, accommodation and food services sector, Republic of Croatia

JEL classification: O14, O30, O33, Z32

Kao posljedica sve većeg tehnološkog napretka i mnogobrojnih inovacija u području informacijsko-komunikacijskih tehnologija, javlja se i sve veća potreba za digitalizacijom i digitalnom transformacijom u poslovanju poduzeća. Posebno značajan utjecaj na uvođenje digitalizacije u poslovanje, odnosno poboljšanje trenutačnog stanja digitalizacije imala je pandemija bolesti COVID-19, koja je pogodila cijeli svijet i pritom uzrokovala mnogobrojne probleme. Međutim, jednako tako postala je katalizator primjene novih tehnoloških rješenja te ubrzala uvođenje mnogobrojnih inovacija. Samim time, očekivanja korisnika usluga smještaja postala su sve veća u području digitalizacije cjelokupne usluge. Stoga će se u ovome radu, osim definiranja pojma i utvrđivanja važnosti digitalne transformacije u poslovanju, analizirati stupanj digitalizacije u poslovanju djelatnosti pružanja smještaja te pripremi i usluživanju hrane u Republici Hrvatskoj, s obzirom na to da predstavlja važan segment u

privlačenju novih gostiju, ali i zadržavanju postojećih, putem vidljivosti na društvenim mrežama te uvođenjem inovacija i novih tehnologija, kao što su aplikacije za rezerviranje smještaja, virtualne i proširene stvarnosti i slično. Istraživanje je provedeno putem anonimne ankete, distribuirane preko elektronske pošte i društvenih mreža. Anketni upitnik sastojao se od sedam grupa pitanja, promatranih po dva kriterija: veličini smještajnih objekata, odnosno tipu objekta, i regiji u kojoj se smještajni objekt nalazi. Ciljana skupina istraživanja bili su vlasnici ili zaposlenici smještajnih objekata koji su dobro upoznati s poslovanjem istraživane djelatnosti. Uzorak je uključivao 106 ispitanika, a rezultati su pokazali da je najveći stupanj digitalizacije u poslovanju analizirane djelatnosti ostvaren u Središnjoj Hrvatskoj, dok je najmanje digitalizirana Gorska Hrvatska. Prema vrsti smještaja, najveći stupanj digitalizacije ostvaren je u hotelskom smještaju, a najmanji stupanj u hostelima. Ispitanici smatraju da ima mjesta za napredak u njihovu poslovanju u pogledu digitalizacije, međutim, mnogi ističu problem nedostatka digitalnih vještina te prevelike troškove uvođenja digitalizacije. Ipak, većina ispitanika spremna je uložiti dodatna sredstva za ostvarivanje većeg stupnja digitalizacije u svom poslovanju. Važan problem nižeg stupnja digitalizacije u poslovanju na području Republike Hrvatske predstavlja i manjak informiranosti o programima i natječajima koji se nude poduzetnicima te velik broj pružatelja smještaja koji ne sudjeluju u besplatnim edukacijama koje bi im pomogle u stjecanju dodatnih digitalnih vještina.

Ključne riječi: digitalizacija, djelatnost pružanja smještaja te pripreme i usluživanja hrane, Republika Hrvatska

JEL klasifikacija: O14, O30, O33, Z32

UVOD

Sve većim tehnološkim napretkom i mnogobrojnim inovacijama u području digitalizacije, javlja se i sve veća potreba za digitalizacijom i digitalnom transformacijom u poslovanju. Porastom korisnika na internetu (Burilović, 2020), rastu i očekivanja trenutnih i potencijalnih korisnika usluga u svim djelatnostima, a time i u djelatnosti pružanja smještaja te pripremi i usluživanju hrane. Pandemija bolesti COVID-19, koja je zahvatila cijeli svijet i uzrokovala brojne izazove, imala je znatan utjecaj na uvođenje digitalizacije u poslovne procese te na unaprjeđenje postojećih razina digitalizacije. Istodobno,

pandemija je djelovala kao snažan katalizator tehnološkog razvoja, potaknuvši ubrzanje inovacija u različitim sektorima. Posljedično, očekivanja korisnika usluga značajno su porasla u pogledu digitalizacije cjelokupnog procesa pružanja usluga. U ovom radu analizirat će se pojam digitalizacije i digitalne transformacije, tehnologije koje se primjenjuju u procesu digitalizacije, stanje digitalizacije u djelatnosti pružanja smještaja te pripremi i usluživanju hrane u Republici Hrvatskoj, te će se putem anketnog istraživanja nastojati utvrditi razina digitalizacije u pojedinim regijama i ocijeniti stanje digitalizacije promatrane djelatnosti s obzirom na vrstu smještajnih objekata.

Digitalna transformacija nezaobilazan je proces u današnjem svijetu, a Republika Hrvatska, kao članica Europske unije, aktivno radi na usklađivanju s visokim standardima digitalnog društva. Međutim, put do potpuno digitaliziranog gospodarstva i društva još uvijek je pred nama. Prema godišnjem izvješću Europske komisije o digitalnom gospodarstvu i društvu (DESI), Republika Hrvatska se u 2023. godini nalazila na 19. mjestu među državama članicama Europske unije po razini digitalnih vještina građana, a zaostaje u području digitalne infrastrukture, digitalnih javnih usluga i integracije digitalnih tehnologija u poslovanje. Posebno je izražen problem nedostatka stručnjaka za informacijske i komunikacijske tehnologije (svega 4,3 % od ukupnog broja zaposlenih), što usporava sam proces digitalne transformacije. S tim se rezultatom Republika Hrvatska nalazi u posljednje četiri države članice Europske unije po postotku zapošljavanja stručnjaka iz područja informacijske i komunikacijske tehnologije (engl. *Information and Communication Technology – ICT*). S druge strane, čak 20,8 % hrvatskih poduzeća svojim zaposlenicima pruža ICT obuku (Eurostat, 2024).

Podaci Eurostata (2024) pokazuju da u Republici Hrvatskoj 63,4 % pojedinaca u životnoj dobi od 16 do 74 godine posjeduje barem osnovne digitalne vještine, dok je prosjek Europske unije 53,9 %. Navedeno je daleko od postavljenog cilja za 2030. godinu, kada je cilj postići najmanje 80 % pojedinaca s osnovnim digitalnim vještinama.

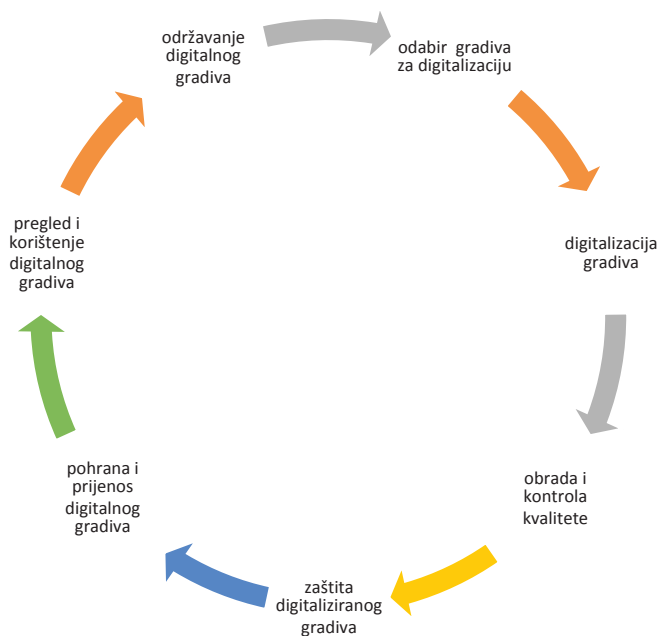
Kako bi se procijenio stupanj digitalizacije u poslovanju djelatnosti pružanja smještaja te pripreme i usluživanja hrane, provedeno je teorijsko i empirijsko istraživanje čiji su rezultati predstavljeni u nastavku rada. Struktura rada organizirana je na sljedeći način: nakon uvodnog dijela, drugo poglavlje pruža teorijski okvir istraživanja. Treće poglavlje opisuje metodologiju istraživanja, dok se u četvrtom poglavlju analiziraju glavni rezultati. Na kraju, peto poglavlje donosi sažetak ključnih zaključaka, uz razmatranje ograničenja i preporuka za daljnja istraživanja.

TEORIJSKI OKVIR ISTRAŽIVANJA

Digitalizacija (engl. *digitization*) se može opisati kao transformacija fizičkih entiteta u digitalne objekte, odnosno kao tehnička konverzija analognih informacija u digitalni oblik (Autio, 2017). Drugi autori opisuju digitalizaciju kao treću industrijsku revoluciju (Greenwood, 1997; Schwab, 2017), kada su tijekom 1960-ih i 1970-ih godina računala postala uobičajena, a automatizacija je zamijenila velik broj ručnih aktivnosti. S druge strane, digitalizacija kao širi pojam (engl. *digitalization*) često se povezuje s jednom ili malim brojem digitalnih tehnologija implementiranih na razini poduzeća. Digitalizacija u tom kontekstu jest pojam koji se često koristi za opisivanje sociotehničkih procesa povezanih s primjenom (širokog spektra) digitalnih tehnologija koje utječu na društvene i institucionalne kontekste, a koji zahtijevaju i sve više ovise o digitalnim tehnologijama (Tilson, Lyytinen i Sørensen, 2010).

Proces digitalizacije poslovanja u poduzeću sastoji se od sedam međusobno povezanih koraka prikazanih na Slici 1.

Slika 1: Koraci u procesu digitalizacije poslovanja u poduzeću



Izvor: Stančić, H. (2009). Digitalizacija. Zagreb: Zavod za informacijske studije.

Proces digitalizacije podrazumijeva konverziju analognih podataka (tekstualnih, slikovnih, audiovizualnih) u digitalni format putem različitih tehnika kao što su optičko očitavanje, digitalizacija zvuka i video snimanje. Ključnu ulogu u ovom procesu ima računalo, čiji napredak u hardverskim i softverskim komponentama omogućava sve efikasniju i sveobuhvatniju digitalizaciju, te time pospješuje razvoj poslovnih procesa (Bosilj Vukšić *et al.*, 2004).

Porastom korisnika novih uređaja spojenih na internet, javlja se i sve veća potreba za procesom digitalne transformacije poslovanja. Navedeno potvrđuje i činjenica da je 2020. godine evidentiran porast od deset milijardi uređaja koji su spojeni s internetom u odnosu na 2018. godinu. Ova činjenica potvrđuje koliko brzo raste broj novih korisnika te samim time i rast potrebe za digitalizacijom poslovanja kako bi se održala prisutnost i/ili rast na tržištu (Burić, 2020).

U suvremenom poslovnom okruženju, korištenje usluga u oblaku postalo je vrlo učestalo. Ova praksa omogućava optimizaciju prostora za pohranu, eliminirajući potrebu za fizičkim skladištenjem dokumenata. Uz to, dokumenti postaju dostupni u svakom trenutku i s bilo koje lokacije, što značajno doprinosi fleksibilnosti poslovanja. U eri digitalne transformacije, ključno je ulagati u promociju kako bi se osigurala vidljivost na sve konkurentnijem tržištu. Zahvaljujući jednostavnom pristupu informacijama, korisnici mogu lako istražiti ponudu poduzetnika i poduzeća, ali istovremeno raste i potreba za diferenciranjem te usmjeravanjem pažnje na specifične potrebe korisnika. Poduzeće se može odlučiti na promociju putem društvenih mreža, internetskih posrednika, svoje mrežne stranice ili elektroničke pošte, kao i tradicionalnim marketinškim kanalima poput letaka, radijskih i televizijskih oglasa. Odabir između medija s kojima će se postići vidljivost ovisi o samom poduzeću, ali i ciljanoj skupini djelatnosti.

Internetski posrednici imaju iznimno važnu ulogu u sektoru iznajmljivanja smještajnih objekata, jer uz tradicionalne metode rezervacije putem telefonskog poziva, elektroničke pošte i mrežnih stranica, pružaju dodatne opcije za rezervaciju. Na taj način smještaj postaje dostupan na još jednoj platformi, što povećava vidljivost među potencijalnim klijentima te povećava mogućnost rezervacije. Platforme kao što su Booking, Airbnb i Expedia sve su popularnije zbog pojednostavljenog procesa rezervacije za korisnike. Nadalje, potaknuti pandemijom bolesti COVID-19, mnogi su iznajmljivači uveli razne promjene i pogodnosti za svoje goste, uključujući nove cjenovne politike, fleksibilne uvjete otkazivanja te kraće roкове za rezervaciju (Matešić *et al.*, 2021). Studija Sigaly i sur. (2022) pokazuje kako su smještajni objekti, potaknuti pandemijom, ubrzano implementirali digitalna rješenja, poput beskontaktno prijave i QR

kodova za pristup informacijama, kako bi se prilagodili novim očekivanjima gostiju.

Prema nacionalnoj klasifikaciji djelatnosti 2007 (NKD), djelatnost pružanja smještaja te pripreme i usluživanja hrane nalazi se u području I. Područje I se nadalje sastoji od razreda 55 koji obuhvaća smještaj te razreda 56 koji obuhvaća djelatnosti pripreme i usluživanja hrane i pića. Glavne su karakteristike ovog područja: pružanje smještaja za posjetitelje, odnosno pružanje smještaja za kraći boravak, kao i priprema i usluživanje hrane za iste posjetitelje. Također, važna karakteristika ove djelatnosti jest to što obuhvaća mnogobrojne sporedne usluge koje se svaki iznajmljivač može odlučiti pružati. Sam obujam dodatnih usluga može varirati o potražnji na tržištu, ali i preferencijama i viziji samog pružatelja smještaja. Ovo područje ne podrazumijeva pružanje boravka na dulje vrijeme, jer se to smatra boravištem te se kao takvo razvrstava u područje L, kao što ne podrazumijeva ni pripremu hrane i pića koje ne konzumiraju posjetitelji, jer se to smatra prodajom na veliko ili malo. Izuzeci u ovoj djelatnosti za pružanje smještaja na duži vremenski period jesu studenti, radnici i slično. Navedena djelatnost prema Svjetskom vijeću za turizam i putovanje (engl. *World Travel & Tourism Council*) zauzima čak 10,4 % globalnog BDP-a, te predstavlja mjesto za 319 milijuna radnih mjesta u cijelom svijetu (Bozhuk *et al.*, 2020).

Pokretačem turističke djelatnosti smatra se trošak i tržište, koji ujedno određuju ponudu i potražnju na tržištu. Ono što se smatra ključnim da digitalno tržište uspije jest primjena informacijske i komunikacijske tehnologije (ICT). ICT tehnologija nalazi se u mnogim ključnim čimbenicima za uspješnu vidljivost smještajnih objekata na tržištu. Stoga je od iznimne važnosti zapošljavanje stručnjaka s naprednim ICT vještinama radi postizanja visoke kvalitete mrežne stranice, unaprjeđenja vidljivosti u području digitalnog marketinga te kontinuiranog upravljanja društvenim mrežama uz praćenje aktualnih trendova. Gosti često preferiraju upoznavanje destinacije i smještajnog objekta putem multimedijских sadržaja kao što su slike i videozapisi, stoga je preporučljivo posvetiti pažnju razvoju tih materijala. Također, preporučuje se kreiranje vlastite aplikacije koja može olakšati boravak gostima u nepoznatoj sredini (Morais *et al.*, 2016).

Dosadašnja znanstvena istraživanja ukazuju na ključnu ulogu digitalnih tehnologija u transformaciji sektora turizma. Tako su Matešić i sur. (2022) istražili kako digitalne platforme redefiniraju distribuciju turističkih usluga, Koo i sur. (2023) istražili primjenu umjetne inteligencije za personalizaciju turističkih iskustava, a Wang i sur. (2022) implementaciju pametnih tehnologija u smještajnim kapacitetima za optimizaciju korisničkog iskustva i povećanje

operativne efikasnosti. Xu i Gursoy (2023) analizirali su kako umjetna inteligencija, putem *chatbotova* i virtualnih asistenata, može povećati zadovoljstvo gostiju pružanjem trenutanih odgovora na upite, personaliziranih usluga i podrške prije, tijekom i nakon boravka. Istraživanje Buhalisa i Amaranggae (2022) naglašava kako su *online* platforme (poput Booking.coma i Airbnb-a) povećale dostupnost smještajnih jedinica, omogućile personalizirane preporuke i ubrzale proces odlučivanja gostiju. S druge strane, Bozhuk i sur. (2020) ističu važnost digitalne ekonomije u povećanju konkurentnosti i održivosti turističkih objekata.

Svrha ovog rada stoga jest istražiti stupanj digitalizacije u djelatnosti pružanja smještaja te pripreme i usluživanja hrane u Republici Hrvatskoj. Analizira se važnost digitalne transformacije u poslovanju, utjecaj pandemije bolesti COVID-19 na ubrzanje procesa digitalizacije, regionalne razlike u stupnju digitalizacije i izazove s kojima se suočavaju pružatelji usluga, poput visokih troškova implementacije i nedostatka digitalnih vještina. Također, istražuje se percepcija i spremnost ispitanika na daljnje ulaganje u digitalizaciju kako bi se povećala konkurentnost i kvaliteta usluga.

Budući da u pregledu postojeće literature nije pronađeno nijedno empirijsko istraživanje koje se bavi stupnjem digitalizacije poslovanja u djelatnosti pružanja smještaja te pripremi i usluživanju hrane u Republici Hrvatskoj, a s obzirom na nedostatak sličnih istraživanja u svijetu, ovaj rad ispunjava značajnu prazninu u tom području.

METODOLOGIJA

Kako bi se analizirao stupanj digitalizacije u djelatnosti pružanja smještaja te pripreme i usluživanja hrane, provedeno je kvantitativno istraživanje primjenom metode ispitivanja, za što je korišten anketni upitnik kreiran putem *Google* obrasca. Ciljana skupina ispitivanja bili su vlasnici smještajnih objekata ili zaposlenici koji su dobro upoznati s poslovanjem smještajnih objekata u Republici Hrvatskoj. Anketni upitnik bio je anonimnog karaktera, a sastojao se od sedam grupa pitanja, promatranih po dva kriterija: prema veličini smještajnih objekata, odnosno tipu objekta te prema regiji u kojoj se smještajni objekt nalazi.

Poziv za sudjelovanje u anketi sadržavao je molbu za sudjelovanje, poveznicu na upitnik, objašnjenje teme, svrhe i predstavljanje organizatora istraživanja, opis prirode ankete, procjenu potrebnog vremena za ispunjavanje (oko 10 minuta), kontakt *e-mail* adrese za dodatne upite te zahvalu.

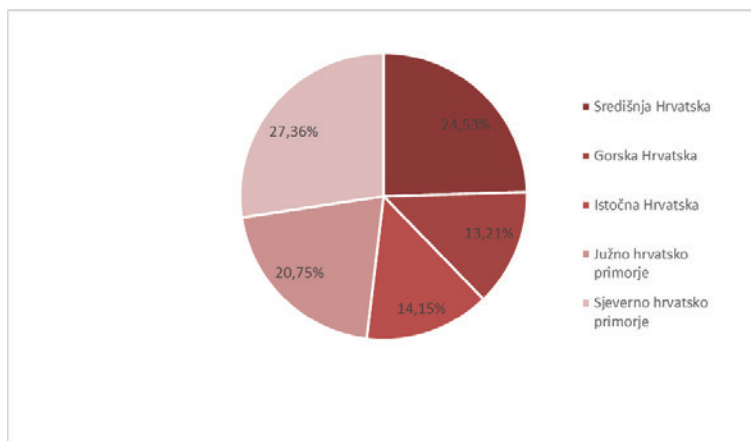
U razdoblju od veljače do studenoga 2024. godine prikupljena su ukupno 352 odgovora, a za analizu je kao relevantan uzorak izdvojeno 106 ispitanika ($N = 106$), koji su odgovarali profilu ispitanika primjerenog predmetnom istraživanju, odnosno izdvojeni su ispitanici koji su vlasnici smještajnih objekata ili zaposlenici koji su dobro upoznati s poslovanjem smještajnih objekata.

REZULTATI ISTRAŽIVANJA

Kao što je prethodno istaknuto, istraživanjem su ispitanici stavovi vlasnika smještajnih jedinica o stupnju digitalizacije u njihovu poslovanju, a najznačajniji rezultati koji su promatrani po veličini smještajnih objekata i regiji u kojoj se smještajni objekt nalazi, detaljno su uspoređeni u nastavku rada.

Grafikon 1. ilustrira regionalnu distribuciju ispitanika, pri čemu najveći udio ispitanika dolazi iz Sjevernog hrvatskog primorja (27,36 % ispitanika), što ovu regiju čini najzastupljenijom u istraživanju. Slijedi Središnja Hrvatska s 24,53 % ispitanika, što također predstavlja značajan dio ukupnog uzorka. Južno hrvatsko primorje zauzima treće mjesto (20,75 %), dok je najmanji udio ispitanika iz Gorske Hrvatske (13,21 % ukupnog broja ispitanika). Istočna Hrvatska obuhvaća 14,15 % ispitanika.

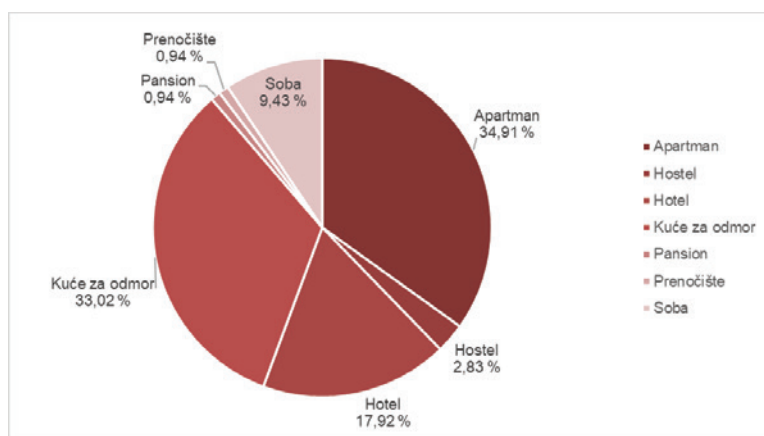
Grafikon 1: Udio ispitanika prema regijama smještajnih jedinica u Republici Hrvatskoj ($N = 106$)



Izvor: Autori

S obzirom na vrstu smještajnih objekata (Grafikon 2), rezultati su pokazali da su najzastupljenije dvije kategorije ispitanika: vlasnici apartmana (34,91 % ispitanika) te vlasnici kuća za odmor (33,02 % ispitanika). Manji udio čine vlasnici hotela (17,92 % vlasnika), te soba (9,43 % vlasnika), što ukazuje na nešto manju zastupljenost u odnosu na apartmane i kuće za odmor. Najmanje su zastupljeni vlasnici hostela (2,83 %), dok su vlasnici pansiona i prenočišta gotovo zanemarivi s po 0,94 %. Važno je napomenuti da pansioni i prenočišta nisu bili izričito ponuđeni kao opcije u upitniku; vlasnici tih objekata sami su dodali te kategorije.

Grafikon 2: Udio ispitanika prema vrsti smještajnih objekata koje nude

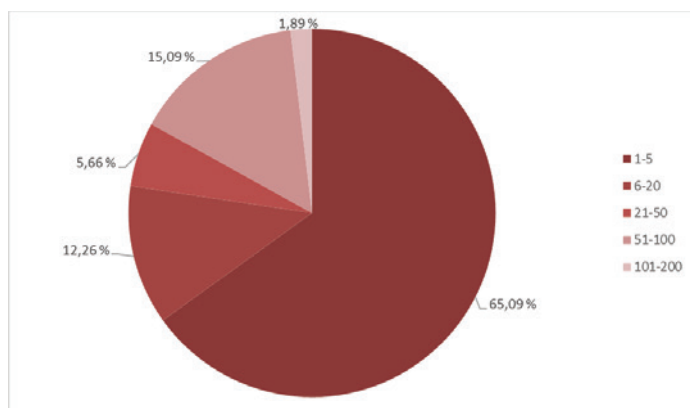


Izvor: Autori

Na Grafikonu 3 prikazana je raspodjela broja smještajnih jedinica među ispitanicima. Rezultati pokazuju da većina ispitanika (65,09 %) posjeduje između 1 i 5 smještajnih jedinica, što je očekivano, s obzirom na prethodnu analizu koja pokazuje da su najčešći objekti apartmani i kuće za odmor, koji uglavnom sadrže manji broj smještajnih jedinica. Značajan, ali manji dio ispitanika (15,09 %) ima 51 do 100 smještajnih jedinica, dok 12,26 % ispitanika posjeduje 6 do 20 jedinica. Manji udio ispitanika ima 21 do 50 jedinica (5,66 %) ili 101 do 200 jedinica (1,89 %). Ovi podaci sugeriraju da većina ispitanika upravlja manjim smještajnim kapacitetima, što je u skladu s njihovom pretežnom orijentacijom prema apartmanima i kućama za odmor. Dodatno, većina ispitanika (38,68 %) izjavljuje da su u djelatnosti smještaja između jedne i pet godina, što ukazuje na to da je velik dio ispitanika nov u ovom poslovanju.

Najmanje ispitanika bavi se ovom djelatnošću više od 31 godine, što sugerira da se radi o sektoru s relativno velikim priljevom novih sudionika i stalnim rastom.

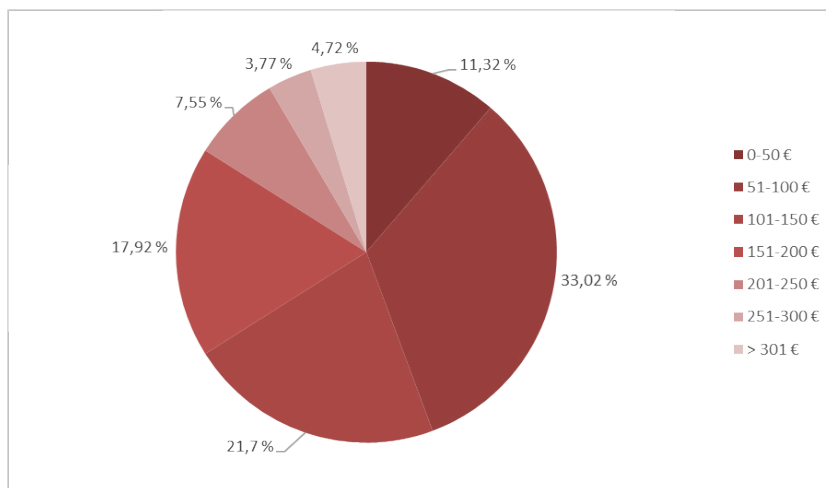
Grafikon 3: Udio smještajnih objekata prema ukupnom broju jedinica



Izvor: Autori

Daljnja analiza odnosila se na analizu cijene jednog noćenja u analiziranim smještajnim jedinicama (Grafikon 4). Rezultati pokazuju da su cijene smještaja značajno porasle uslijed inflacije nakon pandemije bolesti COVID-19. Prema odgovorima ispitanika, većina smještajnih objekata (33,02 %) naplaćuje između 51 i 100 € po noćenju, što predstavlja najčešći cjenovni rang. Navedeno može ukazivati na nastojanje pružatelja usluga smještaja da zadrže pristupačne cijene unatoč porastu troškova. Oko 21 % ispitanika navodi cijene od 101 do 150 € po noćenju, dok 17,92 % ima cijene između 151 i 200 €. Ove srednje cjenovne kategorije također su popularne, što sugerira određenu spremnost gostiju na povećanu potrošnju. Cjenovni rang od 0 do 50 € po noćenju rijetko se pojavljuje (11,32 %), što može odražavati opće povećanje troškova u turizmu. S druge strane, najmanje je smještajnih objekata (4,72 %) koji imaju cijene više od 301 € po noćenju. Manji postotak smještaja naplaćuje između 251 i 300 € (3,77 %), dok 7,55 % objekata ima cijene između 201 i 250 €, što sugerira određenu dostupnost viših cjenovnih opcija, ali uz ograničenu potražnju.

Grafikon 4: Cjenovni rang jednog noćenja u smještajnoj jedinici



Izvor: Autori

Vezano za dobnu strukturu gostiju, najveći broj smještajnih objekata (44,34 %) navodi da im je prosječna dob gostiju između 31 i 40 godina, što ukazuje da je ovaj segment tržišta najčešći korisnik smještajnih usluga. Najmanji postotak (2,83 %) bilježi goste između 19 i 25 godina kao najčešću dobnu skupinu, što može biti posljedica njihove sklonosti alternativnim i jeftinijim vrstama smještaja.

Analiza podataka iz Tablice 1 prikazuje usporedne podatke o stupnju digitalizacije poslovanja djelatnosti pružanja smještaja te usluživanja hrane u različitim regijama Republike Hrvatske. Podaci su rangirani od 1. do 5., gdje 1. označava najviši stupanj digitalizacije (najbolji rezultat), a 5. označava najniži stupanj digitalizacije (najlošiji rezultat). Prikazane kategorije uključuju deset različitih aspekata digitalizacije, poput načina plaćanja, korištenja aplikacija, oglašavanja, implementacije strategija digitalizacije, korištenja e-platформи i prijave za bespovratna sredstva.

Tablica 1: Stupanj digitalizacije poslovanja u djelatnosti pružanja smještaja i usluživanja hrane po regijama u Republici Hrvatskoj (1. – najviši stupanj, 5. – najniži stupanj)

	Gorska Hrvatska	Središnja Hrvatska	Južno hrvatsko primorje	Sjeverno hrvatsko primorje	Istočna Hrvatska
1. Načini plaćanja	5.	1.	3.	2.	4.
2. Dodatne pogodnosti	4.	1.	3.	2.	5.
3. Korištenje aplikacija	5.	4.	1.	2.	3.
4. Povratne informacije	5.	1.	4.	3.	2.
5. Oglašavanje i rezervacija smještaja	5.	1.	2.	3.	4.
6. Administracija	5.	2.	1.	3.	4.
7. Strategija digitalizacije	5.	2.	3.	4.	1.
8. e-Građani	4.	2.	1.	5.	3.
9. eTurizam	3.	1.	4.	5.	2.
10. Korištenje bespovratnih sredstava	5.	2.	4.	3.	1.

Izvor: Autori

Promatrano prema prvom kriteriju, načinima plaćanja u smještajnim objektima po regijama u Republici Hrvatskoj, Središnja Hrvatska prednjači sa 76,92 % objekata koji prihvataju plaćanje karticama i gotovinom, dok Sjeverno hrvatsko primorje prati sa 75,86 %. Južno hrvatsko primorje i Istočna Hrvatska također bilježe solidne rezultate, dok je Gorska Hrvatska najmanje digitalizirana, s približno polovinom objekata koji nude obje opcije plaćanja. Plaćanje isključivo gotovinom najzastupljenije je u Gorskoj Hrvatskoj (28,57 %), dok isključivo kartično plaćanje ostaje marginalno u svim regijama.

Drugi kriterij, dodatne pogodnosti, odnosi se na postojanje, primjerice, gastronomskih i/ili kulturnih tura i radionica, aktivnosti u prirodi, termi i *wellnessa*, izleta brodom, gradskih plaža, događanja i sl. u regijama Republike Hrvatske. Rezultati ukazuju na sve veću važnost dodatnih pogodnosti za lojalne goste. Središnja Hrvatska prednjači sa 65,38 % smještajnih objekata koji već nude neke dodatne pogodnosti, dok 11,54 % planira njihovo uvođenje. Istočna Hrvatska zaostaje, s tek 26,67 % objekata koji nude takve pogodnosti, što ukazuje na potencijal za unapređenje ponude.

Treći kriterij odnosio se na korištenje aplikacija u smještajnim objektima. Sukladno dobivenim podacima, najveći postotak smještajnih objekata s

implementiranom aplikacijom bilježi Južno hrvatsko primorje, gdje 54,55 % objekata koristi aplikaciju, a dodatnih 13,64 % planira je uvesti. Ovi rezultati ukazuju na visok stupanj digitalizacije u ovoj regiji, pri čemu iznajmljivači prepoznaju važnost mobilne prisutnosti za privlačenje i zadržavanje gostiju. Nasuprot tome, u Gorskoj Hrvatskoj nijedan smještajni objekt trenutačno nema aplikaciju, ali čak 42,36 % iznajmljivača planira njezinu implementaciju, što ukazuje na rastući interes za digitalizaciju u ovoj regiji. Ostale regije, poput Istočne Hrvatske te Sjevernog i Južnog hrvatskog primorja, bilježe umjerene stope implementacije aplikacija, uz značajan udio objekata koji planiraju uvođenje takvih alata u budućnosti. Ovi trendovi sugeriraju da turistički razvijene regije prednjače u korištenju digitalnih alata, dok se u regijama s manje turističkog prometa digitalizacija još uvijek razvija.

Četvrti kriterij uključivao je stavove ispitanika o važnosti povratnih informacija gostiju za poslovanje i praksama sakupljanja tih informacija u različitim regijama Republike Hrvatske. Rezultati su pokazali da je svim ispitanicima zajedničko uvjerenje da je dobivanje povratnih informacija od gostiju ključno za unapređenje poslovanja. Sukladno tome, u Središnjoj i Istočnoj Hrvatskoj svi su ispitanici izjavili da aktivno sakupljaju povratne informacije od svojih gostiju, dok u ostalim regijama taj postotak varira.

Peti kriterij odnosio se na mogućnosti rezervacije smještaja u Republici Hrvatskoj prema regijama, s posebnim naglaskom na korištenje internetskih posrednika, društvenih mreža i komunikacije putem *e-maila*. Rezervacija smještaja putem internetskih posrednika pokazuje najvišu razinu zastupljenosti u svim regijama – čak 90,16 % smještajnih objekata u Republici Hrvatskoj koristi ovaj kanal. Posebno se ističe Središnja Hrvatska, gdje svi ispitanici (100 %) nude mogućnost rezervacije smještaja putem internetskih posrednika, dok je prosječan udio rezervacije putem svih mreža u ovoj regiji također najviši (63,8 %). Nasuprot tome, najmanje je zastupljena rezervacije smještaja putem *e-maila*, dok se društvene mreže koriste u samo 53,31 % smještajnih objekata u Republici Hrvatskoj za omogućavanje rezervacija.

Šesti kriterij odnosio se na administraciju poslovanja, odnosno promociju smještajnih objekata i vođenje poslovnih knjiga. Rezultati su pokazali da pružatelji smještaja u Republici Hrvatskoj najčešće poslovanjem upravljaju sami, bez angažiranja stručnjaka s odgovarajućim kompetencijama. Ipak, Južno hrvatsko primorje prednjači po udjelu smještajnih objekata koji su zaposlili stručnjake za ove aktivnosti. U ovoj regiji 68,18 % smještajnih objekata ima stručnjaka za upravljanje promocijom, kao i za vođenje poslovnih knjiga.

Sedmi kriterij odnosio se na postojanje strategije digitalizacije u smještajnim objektima u Republici Hrvatskoj. Iako su ispitanici svjesni ključne važnosti

strateškog planiranja za uspješan proces digitalizacije, kao i nužnosti dosljednog implementiranja tih strategija kako bi digitalizacija u potpunosti ostvarila svoj potencijal, vrlo mali broj ispitanika zapravo primjenjuje ove strategije u praksi. Najveći udio onih koji posjeduju i dosljedno primjenjuju strategiju digitalizacije prisutan je u Istočnoj Hrvatskoj, gdje 26,67 % smještajnih objekata ima razvijenu strategiju koje se pridržavaju. S druge strane, najmanje takvih smještajnih objekata zabilježeno je u Gorskoj Hrvatskoj, gdje nijedan ispitanik nije naveo da posjeduje i dosljedno primjenjuje strategiju digitalizacije.

Osmi kriterij odnosio se na stupanj korištenja e-usluga (konkretno, portala e-Građani) pojedinih smještajnih objekata u Republici Hrvatskoj. Najveći postotak smještajnih objekata koji koriste usluge putem platforme e-Građani zabilježen je u regiji Južno hrvatsko primorje, dok je najmanji udio prisutan u Sjevernom hrvatskom primorju.

Deveti kriterij odnosio se na korištenje platforme eTurizam. U Središnjoj Hrvatskoj, 57,69 % smještaja koristi platformu eTurizam, što predstavlja najveći postotak među regijama. Nasuprot tome, navedena platforma najmanje se koristi u Sjevernom hrvatskom primorju.

Konačno, deseti kriterij odnosio se na korištenje bespovratnih sredstava. Zabrinjavajuća je činjenica da velika većina iznajmljivača nikada nije bila informirana o bespovratnim sredstvima za digitalizaciju koja su im dostupna. Stoga, nije iznenađujuće da se još manji broj njih prijavio na odgovarajući natječaj. Najmanje se prijavilo iznajmljivača iz Gorske Hrvatske te Južnog hrvatskog primorja, gdje se nijedan iznajmljivač nije prijavio na natječaj za dobivanje bespovratnih sredstava za digitalizaciju. Najveći broj prijava zabilježen je u Istočnoj Hrvatskoj, gdje se 33,33 % smještaja prijavilo na natječaj za bespovratna sredstva.

Analiza podataka iz Tablice 2 prikazuje usporedne podatke o stupnju digitalizacije poslovanja djelatnosti pružanja smještaja te usluživanja hrane prema različitim vrstama smještajnih objekata u Republici Hrvatskoj.

Tablica 2: Stupanj digitalizacije poslovanja u djelatnosti pružanja smještaja i usluživanja hrane prema vrsti smještaja u Republici Hrvatskoj (1. – najviši stupanj, 5. – najniži stupanj)

	Apartmani	Hosteli	Hoteli	Kuća za odmor	Sobe
1. Načini plaćanja	3.	2.	1.	5.	4.
2. Dodatne pogodnosti	3.	4.	2.	1.	5.
3. Korištenje aplikacija	2.	1.	4.	3.	5.
4. Povratne informacije	5.	3.	2.	4.	1.
5. Oglašavanje i rezervacija smještaja	5.	3.	1.	2.	4.
6. Administracija	3.	4.	1.	2.	5.
7. Strategija digitalizacije	3.	4.	2.	5.	1.
8. e-Građani	3.	2.	4.	1.	5.
9. eTurizam	3.	4.	5.	2.	1.
10. Korištenje bespovratnih sredstava	3.	4.	5.	2.	1.

Izvor: Autori

Promatrano prema prvom kriteriju, načinima plaćanja u smještajnim objektima, hoteli i hosteli u potpunosti omogućuju plaćanje na oba načina, što se pripisuje velikoj fluktuaciji gostiju i prilagodbi njihovim potrebama. Manji objekti, poput apartmana i kuća za odmor, također sve više nude oba načina plaćanja – 54,3 % kuća za odmor omogućuje plaćanje karticama i gotovinom, dok 45,7 % prihvaća isključivo gotovinu. Rezultati pokazuju da većina smještajnih objekata prati trend diversifikacije plaćanja, no potpuna digitalizacija, poput isključivo kartičnog plaćanja, još nije široko prihvaćena.

Sukladno drugom kriteriju, postojanju dodatnih pogodnosti za goste, u vidu fleksibilnih uvjeta rezervacije i otkazivanja, besplatnog bežičnog interneta, besplatnog parkinga, turističkih informacija i brošura, prostora za prtljagu, poznavanja stranih jezika od strane osoblja, poklona dobrodošlice i sl., rezultati pokazuju da su kuće za odmor među vodećima, s 51,43 % objekata koji nude dodatne pogodnosti za goste i dodatnih 22,86 % koji ih planiraju uvesti. Sobe, zbog ograničenih kapaciteta, imaju najmanji udio dodatnih pogodnosti, dok iznenađuje podatak da značajan dio hotela ne nudi takve usluge. Ovi podaci naglašavaju potrebu za diversifikacijom ponude kako bi se povećala lojalnost gostiju i osigurala konkurentnost.

Analizirajući dobivene odgovore za treći kriterij (korištenje aplikacija), zaključuje se da hosteli (66,67 %) i apartmani (48,65 %) prednjače u korištenju

aplikacija, pri čemu dodatnih 10,81 % apartmana planira uvesti ovu uslugu. Iznenadjujuće, hoteli se, unatoč svojim većim kapacitetima i resursima, nalaze na pretposljednem mjestu s tek 26,32 % objekata koji koriste aplikaciju, što ukazuje na neiskorišten potencijal hotela u primjeni digitalnih alata za unaprijeđenje poslovanja i iskustva gostiju.

Sukladno četvrtom kriteriju (povratne informacije), svi vlasnici soba, hotela i hostela izjavili su da prikupljaju podatke od svojih gostiju, ali upravo su povratne informacije potaknule najveći udio, 80 % vlasnika kuća za odmor, da uvedu neki oblik digitalizacije u poslovanje ili unaprijede postojeće digitalne sustave.

Promatrano prema petom kriteriju (oglašavanje i rezervacija smještaja) prema vrsti smještaja, najveću prosječnu vrijednost svih načina rezervacije smještaja ima hotel, dok najmanje ima apartman. Ovi rezultati ukazuju na snažnu dominaciju internetskih posrednika kao glavnog kanala za oglašavanje i rezervaciju smještaja, dok ostali kanali ostaju manje korišteni u usporedbi.

Analiziranjem dobivenih odgovora prema šestom kriteriju (administracija), pokazalo se da hoteli prednjače u zapošljavanju stručnjaka za promociju, s udjelom od 47,37 %, dok čak 89,47 % hotela zapošljava stručnjake za vođenje poslovnih knjiga. S druge strane, hosteli i sobe najmanje zapošljavaju stručnjake za promociju i vođenje poslovnih knjiga. Zaključno, veći smještajni kapaciteti često omogućuju pružateljima usluga zapošljavanje većeg broja stručnjaka, uključujući one specijalizirane za određena područja.

Sedmi kriterij (strategija digitalizacije) prema vrsti smještaja, pokazao je da čak 60 % soba ima strategiju digitalizacije koje se striktno pridržava, dok kuće za odmor nemaju razvijenu strategiju digitalizacije niti je planiraju uvesti. Ostale vrste smještaja planiraju uvesti strategiju digitalizacije u budućnosti.

Promatrajući osmi kriterij (e-Građani) prema vrsti smještaja, najveći udio u korištenju usluga portala e-Građani iskazali su vlasnici kuća za odmor, a najmanji vlasnici hotela i soba. Također, sukladno devetom kriteriju (eTurizam), vlasnici soba i kuća za odmor iskazali su najveći udio u korištenju platforme eTurizam, a vlasnici hotela najmanji udio, što iznenađuje s obzirom na njihovu općenito veću digitalnu prisutnost.

Promatrajući posljednji, deseti kriterij (korištenje bespovratnih sredstava) prema vrsti smještaja, vidljivo je da vlasnici soba i kuća za odmor dominiraju u korištenju bespovratnih sredstava, dok su vlasnici hotela na zadnjem mjestu, unatoč njihovim resursima i potencijalu za privlačenje sredstava.

DISKUSIJA I ZAKLJUČAK

Digitalna transformacija duboko je prodrla u gotovo sve industrije, a sektor turizma i ugostiteljstva nije iznimka. U djelatnosti pružanja smještaja te pripreme i usluživanja hrane, digitalne tehnologije donijele su brojne promjene koje su utjecale na način poslovanja, odnose s gostima i općenito na konkurentnost na tržištu. Digitalizacija poslovanja ključan je proces usmjeren na transformaciju dokumenata, procesa i zadataka u digitalni oblik radi pojednostavljenja i optimizacije poslovnih aktivnosti. Jedan od važnih aspekata ovog postupka jest angažiranje stručnjaka iz relevantnih područja, s naglaskom na ICT stručnjake. Implementacija novih sustava i softverskih rješenja omogućava smanjenje vremena potrebnog za izvršavanje zadataka, što oslobađa resurse za druge poslovne aktivnosti. Također, otvara se mogućnost suradnje s organizacijama specijaliziranim za podršku u digitalnoj transformaciji, kojima upravljaju stručnjaci s odgovarajućim kompetencijama.

Djelatnost pružanja smještaja te pripreme i usluživanja hrane obuhvaća kratkotrajna putovanja, uključujući i studentske boravke, ali isključuje prodaju hrane ili proizvoda ljudima koji nisu gosti smještaja. U promatranoj djelatnosti, kao važan segment poslovanja ističe se značaj postupka digitalizacije u svrhu privlačenja novih gostiju, ali i zadržavanje postojećih. Proces digitalizacije omogućava i privlačenje novih te zadržavanje stalnih gostiju putem vidljivosti na društvenim mrežama, uvođenjem inovacija i novih tehnologija, poput aplikacija smještaja, virtualne i proširene stvarnosti i slično. Pojavom sve naprednijih tehnologija i inovacija rastu i očekivanja gostiju te samim time i jača konkurencija, a smanjuje se vjernost gostiju.

Ključni nedostaci digitalizacije uključuju visoke troškove implementacije novih tehnologija, nedostatak potrebnih digitalnih vještina među zaposlenicima i njihov otpor prema tehnološkim promjenama. S druge strane, glavne prednosti su povećana učinkovitost i produktivnost, smanjenje operativnih troškova te unaprijeđena analiza poslovnih procesa. Međutim, ograničeni financijski resursi za ulaganje u digitalizaciju često predstavljaju značajnu prepreku u usvajanju digitalnih rješenja.

Rezultati istraživanja provedenog za potrebe ovog rada ukazuju na to da je najviši stupanj digitalizacije postignut u Istočnoj Hrvatskoj, dok je Gorska Hrvatska najslabije digitalizirana regija. S obzirom na vrste smještaja, digitalizacija je najviše zastupljena u hotelskom sektoru, dok hosteli zaostaju u primjeni digitalnih rješenja. Iako Republika Hrvatska trenutačno ima slabiji rezultat u implementaciji strategija digitalizacije u svim regijama, ohrabruje podatak da postoji značajan broj objekata koji imaju razvijenu strategiju, ali se njezina

primjena još uvijek ne provodi u cijelosti. Također, postoji i značajan interes za uvođenjem strategija digitalizacije u budućnosti. Stoga je ključno povećati svijest i osigurati adekvatno informiranje o digitalizaciji, jer je mali postotak ispitanika koji se aktivno educiraju o inovacijama i novim tehnologijama.

Ispitanici prepoznaju mogućnosti za unapređenje svojih poslovnih procesa kroz digitalizaciju, ali često navode nedostatak digitalnih vještina i visoke troškove implementacije kao ključne prepreke. Ipak, većina sudionika istraživanja izražava spremnost za daljnje investicije u digitalizaciju, smatrajući da je riječ o strateškom ulaganju u budućnost, a ne o dodatnom trošku.

Jedan od ključnih problema ograničene digitalizacije u Republici Hrvatskoj jest nedovoljna informiranost o dostupnim programima i natječajima koji mogu podržati digitalnu transformaciju. Uz to, velik broj pružatelja smještaja ne koristi priliku sudjelovati u besplatnim edukacijama koje bi im omogućile stjecanje potrebnih digitalnih vještina. Besplatne platforme poput e-Građani i eTurizam, koje nude korisne informacije i usluge za unaprjeđenje poslovanja, još uvijek su slabo poznate i nedovoljno korištene među pružateljima smještaja, što dodatno usporava proces digitalizacije u sektoru.

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THE TRANSFORMATIVE IMPACT OF ARTIFICIAL INTELLIGENCE ON CORE HUMAN RESOURCE MANAGEMENT FUNCTIONS – A SYSTEMATIC LITERATURE REVIEW

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This systematic literature review examines the transformative impact of artificial intelligence (AI) on Human Resource Management (HRM), addressing three research questions: the transformation of traditional HRM functions by AI systems, the emergence of new functional domains, and the identification of the source of concerns and progress in AI integration. The research followed the PRISMA framework and identified 2661 articles which were validated through three-stage frameworks, and included 265 articles published between 2020 and 2024 from the Web of Science, Scopus and Google Scholar databases for a final analysis. This research utilized the CRANET framework to categorize HRM functions into Resourcing Practices, Employee Development, Compensation and Benefits, and Employee Relationship and Communication.

The findings demonstrate significant technological advancement across HRM functions. In recruitment, Artificial Neural Networks achieved 99% accuracy in candidate evaluation, while Random Forest models predicted retention with 91.8% accuracy. AI Recruiting Models have reduced recruitment processing times from six days to 2.4 minutes. The analysis reveals an uneven research focus, with resourcing practices (n=175) receiving the most attention, while employee relations (n=8) remain understudied. Most studies emphasize AI's positive impact on operational excellence and decision-making. The review identifies the emerging functional domains, including Virtual Human Resource Management

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for remote team management, AI-driven Green HRM for environmental sustainability, and Personalized HRM leveraging advanced analytics for tailored solutions. Critical concerns include ethical issues related to algorithmic bias, trust deficits in AI-driven decision-making, data privacy challenges, and fears of job displacement. However, substantial progress is observed in operational excellence, with AI enhancing efficiency through automated processes and improved decision-making capabilities.

Future research directions emphasize investigation into underexplored HRM functions, predictive compensation strategies, and employee engagement through sentiment analysis. The study recommends longitudinal research in order to understand AI's sustained effects on trust and organizational performance. The development of ethical frameworks and governance models is identified as crucial, along with research into hybrid models blending AI efficiency with human oversight. This review contributes to both theoretical understanding and practical implications of AI in HRM, providing valuable insights for academics and practitioners navigating this technological transformation. The findings underscore the importance of balancing technological advancement with human-centric approaches so as to ensure sustainable and ethical AI integration in HRM practices.

Keywords: *Artificial Intelligence, Human Resource Management, technological transformation, HR functions, HR analytics*

JEL classification: *M12, M14, M15, M54, O33*

INTRODUCTION

The integration of Artificial Intelligence (AI) is fundamentally reshaping organizational operations, with particularly profound implications for Human Resource Management (HRM). AI is not only enhancing the efficiency of HRM processes, but also transforming their underlying structures and strategic orientations (Vrontis et al., 2022; Minbaeva, 2020). As a key pillar of Industry 4.0, AI stands alongside other disruptive technologies such as the Internet of Things (IoT), Big Data, and cloud computing in redefining the modern business environment (Alaghbari et al., 2024; Manroop, Malik & Milner, 2024; Nawaz, Gomes & Faisal, 2021). Post COVID-19, the adoption of AI in HRM has markedly accelerated, driven by the urgent need for digital transformation and organizational agility (Rožman, Tominc & Milfelner, 2023; Avelar et al.,

2024; Bhatt, 2023; Depoo & Hamida, 2024; Al-Omari, Rahrouh & Karsoo, 2023). This evolution transcends mere automation, signaling a fundamental shift in how organizations manage human capital – impacting talent acquisition, development, performance, and retention strategies (Chowdhury et al., 2023; Kiran, Chaubey & Shastri, 2023).

Although a growing body of research explores AI's role in specific HRM functions – such as recruitment (Correa & Frate, 2021; Kshetri, 2022; Mori et al., 2024), performance management (Gupta, Lakhera & Sharma, 2024; Kumar et al., 2024; Dawson & Agbozo, 2024), employee engagement (Divya et al., 2024; Oladipupo & Olubusayo, 2020), and learning and development (Dutta, Mishra & Tyagi, 2023; Wenting et al., 2024) – comprehensive, integrative analyses remain limited. Early studies, such as the one conducted by Black and van Esch (2020), narrowly examined AI's impact within talent acquisition, while Charlwood and Guenole (2022) addressed ethical concerns without exploring functional transformation. More recent efforts (Nguyen-Tat et al., 2024; Brown, 2024; Kumar et al., 2023) have also focused on isolated applications, leaving a gap in understanding AI's broader systemic influence across HRM.

This research paper seeks to address this gap by offering a holistic, systematic analysis of how AI is reshaping the all-core functions of HRM. Specifically, it aims to: I) Analyze the transformation of traditional HRM functions through AI systems; II) Identify emerging functional domains within HRM driven by AI integration; and III) Examine the evolving concerns and advancements associated with AI implementation in HRM practices.

To this end, the study addresses the following research questions:

RQ1: How are AI systems transforming the traditional core functions of HRM?

RQ2: What new functional domains have emerged within HRM due to AI systems integration?

RQ3: What are the emerging sources of concern and progress resulting from AI systems integration in HRM?

The remainder of this paper is structured as follows: the next section presents the conceptual background and theoretical framework. This is followed by the methodology, which details the systematic literature review process based on the PRISMA framework. The results are presented in alignment with the research questions, followed by a discussion of the key findings. The paper concludes with the contributions, limitations, and directions for future research.

BACKGROUND

The emergence of AI in HRM represents a significant evolution in how organizations manage their human capital. This section provides context on AI technologies in HRM and establishes the theoretical framework used to analyze HRM functions.

AI IN HRM

AI refers to computer systems capable of performing tasks traditionally requiring human intelligence, such as learning, reasoning, problem-solving, perception, and language understanding (Russell & Norvig, 2020). In HRM, AI encompasses technologies including machine learning, natural language processing, computer vision, expert systems, and predictive analytics that automate or augment decision-making and HR processes (Strohmeier & Piazza, 2015). As a cornerstone of Industry 4.0, AI is among the most transformative technologies in contemporary business, alongside IoT, Big Data, and cloud computing (Alaghbari et al., 2024; Manroop et al., 2024; Nawaz et al., 2021). HRM scholars have traced technological evolution over six decades – from early Electronic Data Processing (EDP) systems to AI-driven solutions that enhance efficiency, support data-driven decisions, and enable personalized employee experiences (Kim et al., 2021; Li et al., 2023; Bhardwaj et al., 2020). AI applications now span various HRM functions, including talent acquisition and employee well-being monitoring (Gayatri, Lavanya, Rajitha, Butta & Supraveen, 2023; Pillai R., Sivathanu B., 2020; Konovalova V., Mitrofanova, Mitrofanova & Gevorgyan, 2022). However, alongside its benefits, AI presents challenges around trust, ethics, privacy, and preserving human dignity in organizational practices (Khushk A., Zhiying L., Yi X., Zhang X., 2024; Arslan, Cooper, Khan, Golgeci & Ali, 2022). An effective integration of AI into HRM necessitates balancing technological potential with human-centric values (Fenwick, Molnar & Frangos, 2024; Bankins et al., 2022).

THEORETICAL FRAMEWORK: HRM FUNCTIONS

This study employs the functional classification developed by the Cranfield Network on International Human Resource Management (CRANET) in order to systematically analyze AI's impact on HRM. Founded in 1989, CRANET

represents a collaborative academic initiative across 50 countries, renowned for HRM research methodology and theoretical frameworks (Parry, Stavrou & Lazarova, 2020). The CRANET 2021 survey provides an empirically validated framework identifying four key HRM functions: (I) Resourcing Practices: recruitment, selection, workforce planning, and talent acquisition; (II) Employee Development: training, learning, performance management, and career development; (III) Compensation and Benefits: reward systems, pay structures, benefits administration, and incentives; (IV) Employee Relationships and Communication: employee engagement, industrial relations, organizational communication, and well-being initiatives.

This classification was selected for its established international credibility, comprehensive categorization, and robust methodological foundation for analyzing technological impacts across diverse contexts (Charlwood and Guenole, 2022; Nguyen-Tat, Bu & Ngo, 2024; Brown J.G., 2024). While studies have explored specific AI applications in isolated HR processes (Charlwood and Guenole, 2022; Nguyen-Tat, Bui & Ngo, 2024; Brown J.G., 2024; Kumar MR, Gunjan & Ansari, 2023), limited research has systematically examined how these technologies impact all core HRM functions and create new functional domains. This systematic literature review addresses this gap by examining AI's transformative impact across all core HRM functions.

METHODOLOGY

In order to address the research questions, this study employs a Systematic Literature Review (SLR) methodology based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, building on previous limited-scope reviews (Black & van Esch, 2020). This transparent and systematic approach, recommended for delimited and context-specific research, provides a rigorous foundation for analyzing AI's impact on HRM functions (Matthew J Page et al., 2021; Pereira et al., 2023).

RESEARCH DESIGN

The systematic literature review was designed to comprehensively identify, evaluate, and synthesize research on AI applications across all core HRM functions. This methodology was selected for its capacity to identify patterns,

gaps, and emerging trends in a rapidly evolving field. The SLR followed three distinct methodological stages: Identification, Screening, and Inclusion.

THEORETICAL FRAMEWORK

In order to establish a clear framework for understanding HRM functions, the study adopts the categories developed by the CRANET research network. Established in 1989, CRANET represents a collaborative academic initiative spanning 50 countries and is a recognized source for HRM research methodology. While there are various perspectives on HRM's core functions, the CRANET 2021 survey questionnaire provides a comprehensive, empirically validated framework identifying four key HRM functions: resourcing practices, employee development, compensation and benefits, and employee relationships and communication. This classification was selected for its established credibility in international HRM research and robust methodological foundation.

Search strategy and keyword selection

The database queries for the systematic literature review were designed using three key concept blocks: HRM terminology, AI and related technologies, and the four core HRM functions. The keyword selection process involved iterative refinement so as to balance comprehensiveness with relevance:

- I. HRM Terminology: "Human Resource", "HR management", "HRM"
- II. AI Technologies: "artificial intelligence", "AI", "machine learning", "deep learning", "natural language processing", "predictive analytics"
- III. HRM Functions: Keywords related to all functions & sub functions within each CRANET domain

This approach ensured that the search would capture literature at the intersection of AI technologies and all HRM functions, aligning directly with our research questions. The search strategy balanced specificity with sensitivity to capture both broad applications and targeted implementations.

DATA COLLECTION PROCESS

The SLR was conducted in three sequential stages:

Stage 1 – Identification

This phase involved identifying relevant literature through comprehensive searches in the Web of Science, Scopus, and Google Scholar, along with for-

ward and backward citation methods. The queries were designed to capture AI applications in HRM on core functions identified. Additional sources, such as organizational reports and government documents, were explored, with Google Scholar used for snowballing citations.

Web of Science Query: TS((((“human resource” OR “HR management” OR “HRM”) AND (“artificial intelligence” OR “AI” OR “machine learning” OR “deep learning” OR “natural language processing” OR “predictive analytics”) AND (“recruitment” OR “talent acquisition” OR “employee selection” OR “hiring” OR “candidate screening” OR “applicant tracking” OR “training” OR “learning development” OR “skill development” OR “employee development” OR “competency development” OR “performance management” OR “performance evaluation” OR “performance assessment” OR “performance appraisal” OR “compensation” OR “employee engagement” OR “employee experience” OR “employee relations” OR “HR analytics” OR “workforce planning” OR “HR policy”)))).

Scopus Query: TITLE-ABS-KEY((((“human resource” OR “HR management” OR “HRM”) AND (“artificial intelligence” OR “AI” OR “machine learning” OR “deep learning” OR “natural language processing” OR “predictive analytics”) AND (“recruitment” OR “talent acquisition” OR “employee selection” OR “hiring” OR “candidate screening” OR “applicant tracking” OR “training” OR “learning development” OR “skill development” OR “employee development” OR “competency development” OR “performance management” OR “performance evaluation” OR “performance assessment” OR “performance appraisal” OR “compensation” OR “benefits” OR “payroll” OR “rewards management” OR “employee engagement” OR “employee experience” OR “employee relations” OR “HR analytics” OR “workforce planning” OR “HR policy”)))).

INCLUSION AND EXCLUSION CRITERIA

Clear parameters were established to ensure the relevance and quality, as detailed in Table 1. Key criteria included the publication date (2020 and later), topic relevance, source credibility, and language (English only). These criteria helped maintain focus on contemporary applications in HRM.

Table 1: Inclusion and exclusion criteria

Sl. No.	Criterion	Include	Exclude
1	Topics	Topics related to AI systems and functions of HRM; AI and HRM	Topics that are not related to the search context
2	Date	Studies published from 2020 and later	Studies published before 2020
3	Main Source	The studies from Scopus, Web of science, Google Scholar	Studies from other journals
4	Area of Research	Business Management Economics, Applied Psychology, Computer Science & Social Science	Articles in the other areas of research
5	Secondary Source	Company documents, websites, and papers on the listed topics	Secondary sources that do not contain the listed topics
6	Document Type	Article, early access, Proceeding Paper, review articles	Other document types
7	Location	Not specific to any location	NA
8	Language	English language studies	Studies in other languages

Source: Authors

Stage 2 – Screening

This stage involved a systematic evaluation of retrieved articles against the established inclusion/exclusion criteria. This multi-stage filtering process began by reviewing titles, abstracts, and keywords to eliminate irrelevant records or those with semantic ambiguity. The screening was conducted independently by two researchers in order to reduce selection bias, with disagreements resolved through discussion.

Stage 3 – Inclusion

The final and critical stage involved an in-depth assessment of full texts that passed the screening stage. Each article was evaluated for methodological quality, theoretical contribution, and relevance to the research questions. This stage ensured that only substantive, high-quality research was included in the final analysis.

ANALYTICAL APPROACH

The articles included were analyzed using thematic content analysis so as to identify patterns and trends related to the three research questions. This involved the following:

- I. Mapping articles according to the HRM functions established
- II. Identifying AI technologies deployed within each function
- III. Analyzing reported outcomes, both positive (progress) and negative (concerns)
- IV. Mapping emerging functional domains

This analytical approach enabled a comprehensive understanding of how AI is transforming HRM functions while maintaining systematic rigor throughout the process.

RESULTS

Our Systematic Literature Review using the PRISMA 2020 flow diagram yielded a total of 265 articles published between 2020 and 2024, that met all the inclusion criteria.

IDENTIFICATION

The initial search retrieved 2661 records (629 from the Web of Science, 2032 from Scopus). After removing 469 duplicates, 2192 unique records remained. Given the emergent nature of research at the intersection of AI and HRM, only publications from 2020 to October 2024 were included, resulting in the exclusion of 379 records. A further 79 non-English publications and 1244 thematically irrelevant studies were excluded. Additional 132 records were extracted from organizational reports, websites, and citation chaining. In total, 645 articles were included for the screening.

SCREENING

At this stage, the titles, abstracts, and keywords of the identified records were reviewed to assess their relevance to the research topic. A total of 214 records were excluded due to either thematic irrelevance or lexical ambiguity.

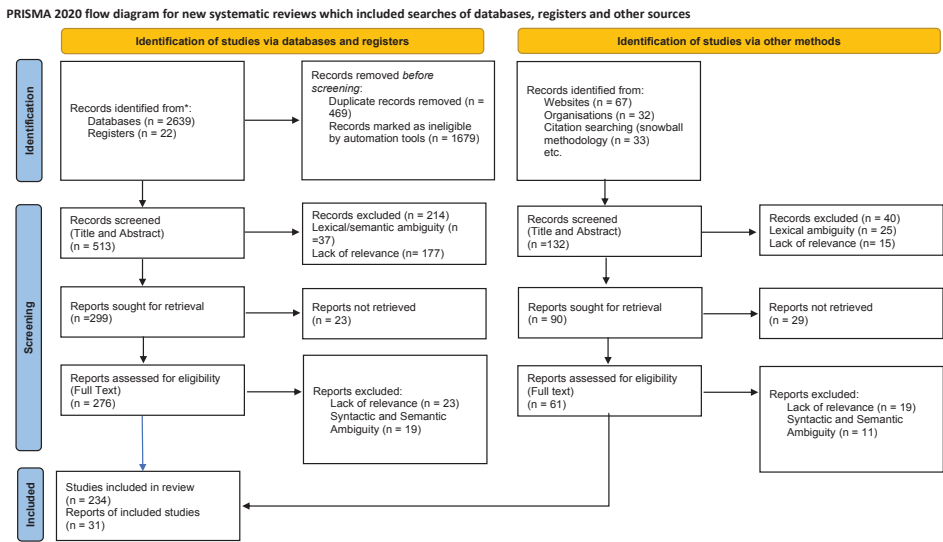
The remaining 299 records were deemed potentially eligible, and efforts were made to retrieve their full texts. Despite exhaustive attempts, 23 articles could not be accessed due to availability constraints. Consequently, 276 articles were successfully retrieved, and together with previously sourced materials, a total of 337 full-text articles were included for comprehensive review.

INCLUSION

A total of 337 full-text articles retrieved were subjected to a rigorous eligibility assessment. Articles demonstrating limited relevance to the research scope or exhibiting syntactic and semantic ambiguity were excluded. Following this screening, a total of 265 articles were retained for final inclusion. These 265 studies, characterized by their substantive quality and relevance, formed the foundation for the final analysis.

The detailed flow of the identification, screening, and inclusion process is illustrated in the PRISMA flow diagram in Figure 1.

Figure 1: PRISMA 2020 flow diagram



Template Source: Page MJ, et al. BMJ 2021;372:n71. <https://doi.org/10.1136/bmj.n71>

The analysis reveals a progressive increase in research publications related to AI in HRM, reflecting the growing scholarly interest in this domain during the review period.

Table 2: YoY increase in No. of publications

Year of publication	No. of relevant articles	Percentage
2020	21	8%
2021	24	9%
2022	44	17%
2023	69	26%
2024	107	40%
Total	265	100%

Source: Authors

RQ1: HOW ARE AI SYSTEMS TRANSFORMING THE TRADITIONAL CORE FUNCTIONS OF HRM?

Our analysis reveals a comprehensive transformation of traditional HRM functions through AI integration, with varying degrees of implementation across the functional domains defined by the CRANET framework. Research findings reveal that AI systems have fundamentally transformed core HRM functions. The distribution of articles across core HRM functions is illustrated in Table 3.

Table 3: Distribution of articles across core HRM functions

HRM core functions	No. of articles	Percentage
Resourcing practices	175	66%
Employee development	92	35%
Compensation and benefits	39	15%
Employee relationship and communication	9	3%

Source: Authors

Note: Some articles address multiple HRM functions, resulting in overlapping categorizations

RESOURCING PRACTICES TRANSFORMATION

Resourcing practices received predominant academic focus (175 articles, 66% of corpus). Machine learning, NLP, and deep learning have revolutionized recruitment through automated resume screening, candidate matching, and real-time decision-making (Aleisa et al., 2023; Gowrabhathini, Arulini, Priya, Hemanandu, Veera Satya Bhargavi & Varshini, 2024; Tian, Pavur, Han & Zhang, 2023). ANN implementations demonstrated 99% accuracy in candidate evaluations (Amzile et al., 2022), while Random Forest models achieved 91.8% accuracy in predicting employee retention (Marvin et al., 2021). AI Recruiting Models using BIRCH and RoBERTa reduced recruitment processing from six days to 2.4 minutes (Aleisa et al., 2023). These advances have transformed traditional recruitment, enabling more efficient and objective processing of larger candidate pools (Black & van Esch, 2020; Yu et al., 2023; Zheng, Zhao, Usman & Poulouva, 2024).

EMPLOYEE DEVELOPMENT TRANSFORMATION

Employee development garnered significant focus (92 articles, 34.7% of corpus). Machine learning algorithms analyze performance data to identify skill gaps and create targeted interventions (Kumar et al., 2023; Pan & Froese, 2023). Predictive analytics identify high-potential employees with enhanced accuracy, enabling tailored career paths (Gupta & Kumar, 2024). Performance management increasingly leverages AI-driven analytics and real-time feedback (Qin et al., 2023; Parveen, Malpani, Rasheed & Sultana, 2024). Singh and Khatun (2024) demonstrated significant improvements in knowledge retention through AI-facilitated virtual reality training, while Chanda and Ghosh (2024) documented enhanced evaluation objectivity. Conversational AI provides just-in-time learning support, improving adaptability and engagement (Gowrabhathini et al., 2024), and resulting in more agile, data-driven development strategies.

COMPENSATION AND BENEFITS TRANSFORMATION

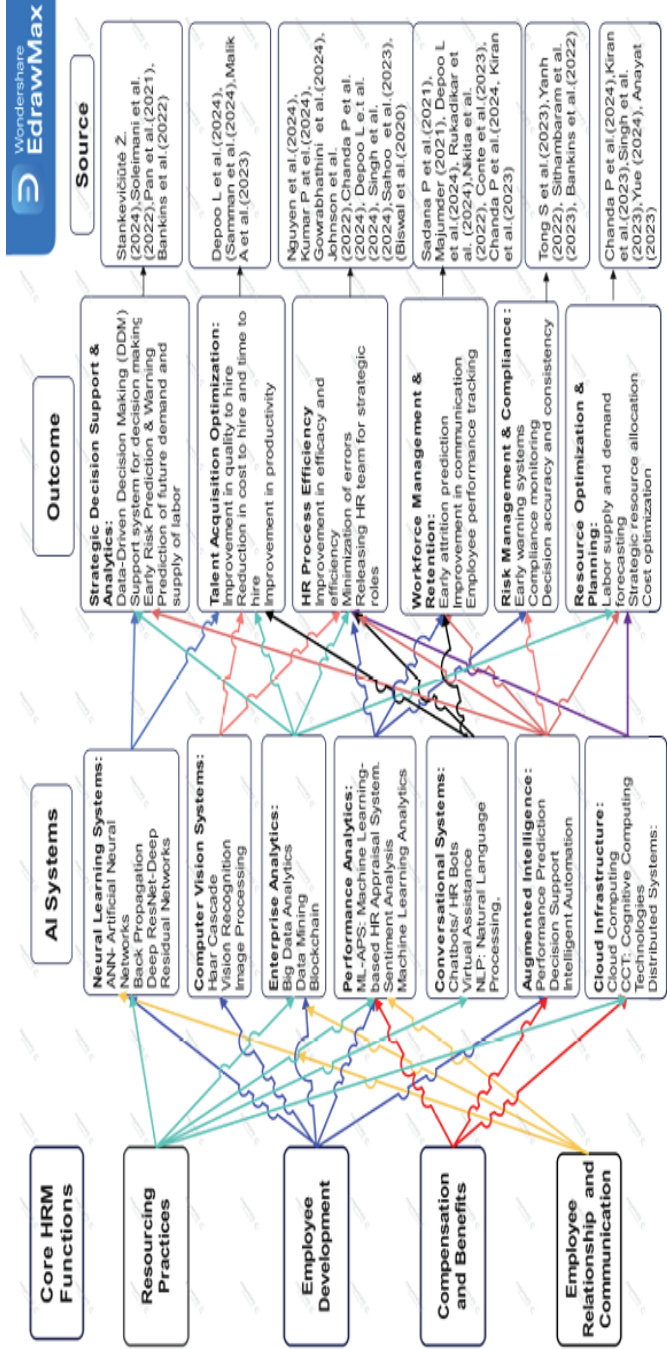
Compensation and benefits received less focus (39 articles, 14.7% of corpus). Advanced analytics have improved salary benchmarking accuracy and reduced errors (Rabenu & Baruch, 2024; Tairov et al., 2024), while predictive models enhance forecasting of compensation impacts on retention (Jatobá et al., 2023). Cloud-based systems with AI integration reduced administration time while improving competitiveness through real-time market analysis (Marler, 2024). RPA in payroll processing decreased processing times and error rates (Yabanci, 2023). AI-powered simulations support cost-effective compensation planning (Kumar et al., 2024; Alaghbari et al., 2024), enabling strategic decisions that balance employee satisfaction with organizational sustainability.

EMPLOYEE RELATIONSHIP AND COMMUNICATION TRANSFORMATION

This function received disproportionately low research emphasis (9 articles, 3.4% of corpus). AI transforms employee relations through chatbots and sentiment analysis tools, with virtual assistants managing routine HR inquiries (Majumder & Mondal, 2021) and predictive analytics forecasting sentiment trends (Lee & Song, 2024). Organizations implementing AI-driven communication systems report improved employee engagement metrics (Nikita & Velicheti, 2022). AI tools facilitate internal communication, aiming to understand employee concerns and foster positive engagement (Nosratabadi, Zahed, Ponkratov & Kostyrin, 2022).

Figure 2 illustrates how AI systems are integrated across various HRM functions, producing significant operational outcomes. Organizations reported better operational efficiency (Stankevičiūtė, 2024), improved decisions through data analytics (Kumar et al., 2024), cost effective HR operations (Alaghbari et al., 2024), and better hiring results (Black & van Esch, 2020; Yu et al., 2023; Zheng et al., 2024) due to this integration.

Figure 2: AI Systems in HRM functions and their outcome



Source: Authors

RQ2: WHAT NEW FUNCTIONAL DOMAINS HAVE EMERGED WITHIN HRM DUE TO AI SYSTEMS INTEGRATION?

In the context of HRM, a domain typically refers to a specific area or function within the broader field. The integration of AI systems in HRM has driven several transformative trends. We identified five distinct emerging domains as presented in Table 4.

VIRTUAL HUMAN RESOURCE MANAGEMENT (VHRM)

VHRM enables effective remote team management through improved communication and technological adaptation (Depoo & Hermida, 2024), extending traditional HRM functions into digital environments, accelerated by events like COVID-19.

AI-ENABLED GREEN HRM

This domain combines technology with environmental sustainability, fostering sustainable organizational strategies (Abid, Faisal, Al-Esmael, Farooq & Nassour, 2024; Shayegan, Bazrkar, & Yadegari, 2023; Ogbeyebu, Emelifeonwu, Pereira, Oseghale, Gaskin, Sivarajah & Gunasekaran, 2024). It leverages AI to monitor environmental metrics and align HR with organizational sustainability goals.

PERSONALIZED HRM

Leveraging HR analytics, this domain delivers tailored solutions at the individual level, shifting toward next-generation practices (Huang, Yang, Zheng, Feng & Zhang, 2023; Prasad & De, 2024). It provides customized employee experiences, development paths, and compensation structures.

NEW HR ROLES AND COMPETENCIES

AI integration has created new roles requiring expertise in AI, data analytics, and ethical governance (Glebova, Madsen, Mihaľová, Géczi, Mittelman

& Jorgič, 2024; Malik et al., 2022; Hao, Ng, Aman & Zhang, 2024), including positions like Chief AI Officers and AI Ethics Officers.

AI-DRIVEN E-HRM

These strategies revolutionize employee performance and productivity by optimizing HRM practices (Samman & Obaidly, 2024; Alan, 2023; Bag, Dhamija, Pretorius, Chowdhury & Giannakis 2022), representing comprehensive digital transformation through integrated platforms and automated systems.

Table 4: Emerging domains due to usage of AI in HRM functions

Emerging domains	Reference
VHRM	Depoo et al. (2024)
AI enabled Green HRM	Shayegan, S. et al. (2023), Abid, U. et al. (2024), Hao et al. (2024), Ogbeibu et al. (2024)
Personalized HRM	Prasad et al. (2024); Huang X et al. (2023), Malik et al. (2022)
Emergence of new Jobs/ Roles (CAIO)	Glebova, E. et al. (2024), IBM, Forbes (2024)
AI driven e-HRM	Samman et al. (2024), Alan (2023), Kambur, E. et al. (2023)

Source: Authors

RQ3: WHAT ARE THE EMERGING SOURCES OF CONCERN AND PROGRESS RESULTING FROM AI SYSTEMS INTEGRATION IN HRM?

The integration and implementation of AI systems in HRM has raised several significant concerns among researchers and practitioners, while highlighting operational excellence as the major source of progress, and a summary of this is presented in Table 5.

Table 5: Summary of researched articles

HRM Functions	No. of articles	Source of progress	Source of concern	Neutral
Resourcing Practices	175	151	17	7
Employee development	92	77	10	5
Compensation and benefits	39	31	5	3
Employee relationships and communication	9	7	1	1

Source: Authors

SOURCES OF CONCERN

AI integration in HRM raises several critical concerns spanning ethical, trust, privacy, skill, job displacement, and dehumanization issues, as shown in Table 6.

Ethical Issues: Key challenges include addressing algorithmic bias, discrimination, and fairness concerns (Mori et al., 2024; Bankins et al., 2022; Prikshat, Patel, Varma & Ishizaka, 2022). Ethical frameworks are essential in order to mitigate algorithmic manipulation and employee surveillance risks (Manroop et al., 2024; Bar-Gil, Ron & Czerniak, 2024). Mori et al. (2024) highlight the ethical implications from utilitarian optimization, justice, and human rights perspectives. AI systems may perpetuate discriminatory hiring practices, thus violating ethical standards (Lukaszewski & Stone, 2024).

Trust Issues: Trust remains a significant adoption barrier, with employees often preferring human decision-makers (Bankins et al., 2022). Skepticism persists regarding AI's role in performance evaluations, with concerns over emotional impacts (Park et al., 2021; Arora & Mittal, 2024). Distrust stems from perceived ethical flaws in AI-based hiring (Figueroa-Armijos, Clark & da Motta Veiga, 2023; Zahedi Nejad, Sabokro & Oikarinen, 2024).

Data Privacy Concerns: AI usage amplifies privacy challenges in handling sensitive employee data. Generative AI tools in recruitment highlight the need for stringent data protection and transparency (Budhwar et al., 2023; Rudadikar & Khandelwal, 2024). Effective governance frameworks must address data collection concerns (Khushk et al., 2024; Dutta et al., 2023).

Skill Gaps: Organizations face challenges in managing AI systems, with HR professionals requiring new competencies for ethical AI integration (Charlwood & Guenole, 2022; Konovalova et al., 2022). Resource constraints hinder the adoption in private-sector companies (Melliani et al., 2024).

Job Loss Fears: AI-driven processes generate job displacement concerns among HR professionals. Despite efficiency gains, skepticism about job losses persists (Ore & Sposato, 2022; Bedi, Arora, Badoni & Paras, 2024), thus requiring role reimagination (Fedotova, Kozlova & Bin, 2022).

Dehumanization of HR Processes: AI integration raises concerns about reduced empathy in decision-making (Konovalova et al., 2022; Hofeditz, Clausen, Rieß, Mirbabaie & Stieglitz, 2022). Preserving human dignity remains crucial (Andrieux, Johnson, Sarabadani & Van Slyke, 2024; Bhargava & Assadi, 2024).

Table 6: Sources of concern due to AI-HRM Integration

Source of concern	Reference
Ethical issue	Tsiskaridze et al. (2023), Bar-Gil, O. et al. (2024), Manroop, L. et al. (2024), Prikshat, V. et al. (2022), Charlwood et al. (2022), Mori, M. et al. (2022), Andrieux, P. et al. (2024), Figueroa et al. (2023)
Trust issue	Bankins et al. (2022), Ligeiro, N. et al. (2024), Zahedi et al. (2024), Dutta, D. et al. (2023), Ore et al. (2022), Park et al. (2021)
Data privacy/protection	Rukadikar et al. (2024), Tsiskaridze et al. (2023), Fedotova et al. (2022), Khan, S. et al. (2024), Anayat (2023)
Dehumanization	Bankins et al. (2022), Konovalova et al. (2022), Bar-Gil, O. et al. (2024), Manroop L. et al. (2024)
Lack of skilled resources	Melliani et al. (2024), Anayat (2023)
Loss of jobs	Bedi et al. (2024), Anayat (2023)

Source: Authors

SOURCES OF PROGRESS

AI integration in HRM has enhanced the efficiency and effectiveness of HRM functions. These sources of progress are enumerated in Table 7.

Operational Excellence: AI-driven automation enhances efficiency by streamlining data analysis, decision-making, cost reduction, and resource allocation (Singh & Khatun, 2024; Alaghbari et al., 2024). Machine learning and blockchain improve performance evaluations, minimizing subjectivity (Chanda & Ghosh, 2024). Recruitment processes benefit from AI’s precision in candidate selection and bias reduction via advanced feature extraction techniques (Zheng et al., 2024; Gowrabhathini et al., 2024). Predictive analytics aids strategic workforce planning, optimizing resource allocation and human capital investment (Samman & Obaidly, 2024; Johnson, Coggburn & Llorens, 2022).

Emergence of New Skills: AI integration drives the need for HR professionals to develop new competencies. Charlwood and Guenole (2022) emphasize ethics, fairness, and effective AI tool usage, while Konovalova et al. (2022) advocate for AI management skills. Organizations investing in upskilling for AI adaptation report better operational performance and employee engagement (Singh, Singh & Chakraborty, 2024; Melliani et al., 2024). These new skills transform HR professionals into strategic partners, aligning AI with organizational objectives.

Table 7: Sources of progress due to AI-HRM Integration

Source of progress	References
Operational Excellence	Nguyen et al. (2024), Kumar, P. et al. (2024), Gowrabhathini et al. (2024), Johnson et al. (2022), Chanda, P. et al. (2024), Depoo & Hermida (2024), Hu (2022), Shi hu (2024), Singh et al. (2024), Sahoo et al. (2023), Biswal et al. (2020)
Opportunity for new skills, new jobs creation	Bedi et al. (2024), Glebova, E. et al. (2024), Kronberger, Z. et al. (2024)

Source: Authors

DISCUSSION

This systematic literature review provides comprehensive insights into the transformative impact of AI on HRM functions, addressing a significant research gap regarding the holistic understanding of AI’s role in reshaping traditional HR practices and creating new functional domains. By analyzing 265 articles published between 2020 and 2024, this study advances prior research, which has often focused on isolated applications (Black & van Esch, 2020; Charlwood & Guenole, 2022), by presenting a synthesized understanding of AI’s broader impact.

TRANSFORMATION OF TRADITIONAL HRM FUNCTIONS

Our analysis demonstrates that AI has fundamentally transformed core HRM functions by shifting from intuition-driven to data-centric decision-making (Black & van Esch, 2020; Zheng et al., 2024). The implementation of

sophisticated AI tools such as ANN, Random Forest, SVM, and conversational AI interfaces has significantly enhanced HR processes (Amzile et al., 2022; Gowrabhathini et al., 2024; Marvin et al., 2021; Nosratabadi et al., 2022). These technological advancements have facilitated a paradigm shift from intuition-based to data-driven decision-making in HRM.

The uneven distribution of research focus across HRM functions, with resourcing practices receiving substantial attention (n=175) compared to employee relations (n=9), reveals an important pattern in current scholarly discourse. This imbalance suggests that AI's integration has been inclined in functions with more quantifiable outcomes and structured data inputs, reflecting the complexity of embedding AI in relational and emotionally nuanced domains (Bankins et al., 2022).

AI's ability to deliver 99% candidate evaluation accuracy and predict employee retention with 91.8% precision (Amzile et al., 2022; Marvin et al., 2021), alongside drastically reduced recruitment times (from six days to 2.4 minutes) (Aleisa et al., 2023), illustrates the significant operational gains that AI enables. These align with broader Industry 4.0 transformations integrating AI, IoT, and Big Data (Alaghbari et al., 2024; Nawaz et al., 2021). The COVID-19 pandemic further accelerated AI adoption, prompting a shift toward resilient, digitally enabled HR solutions such as virtual onboarding and digital engagement (Rožman et al., 2023; Avelar et al., 2024), highlighting AI's strategic relevance in organizational agility.

EMERGENCE OF NEW FUNCTIONAL DOMAINS

Our analysis identifies five emerging functional domains that extend beyond traditional HRM frameworks: Virtual HRM, AI-enabled Green HRM, Personalized HRM, New HR Roles, and AI-driven e-HRM. These represent not merely functional innovations, but conceptual shifts redefining HRM's scope.

The emergence of VHRM enables effective remote team management and retention through improved communication and technological adaptation (Depoo & Hermida, 2024; Kambur & Yildirim, 2023). This domain has gained particular prominence following the global shift toward remote work, demonstrating how AI can facilitate human capital management in distributed work environments.

AI-enabled Green HRM represents an innovative intersection of technology and sustainability, fostering environmentally sustainable organizational strategies (Abid et al., 2024; Shayegan et al., 2023; Ogbeibu et al., 2024). This

domain illustrates how AI can help align HRM practices with broader organizational and societal objectives, reinforcing the strategic role of HRM in addressing environmental challenges.

Personalized HRM, by leveraging advanced HR analytics, enables tailored HR solutions at the individual level, representing a shift toward next-generation HR practices (Huang et al., 2023; Prasad & De, 2024). This domain reflects a fundamental shift from standardized HR approaches to personalized employee experiences, facilitated by AI's capacity to analyze individual performance patterns, learning preferences, and career aspirations.

New HR roles – such as Chief AI Officers and AI Ethics Officers – reflect the evolving competencies required in AI-integrated environments (Glebova et al., 2024; Malik et al., 2022). AI-driven e-HRM, through automated workflows and intelligent platforms, is reconfiguring HRM into a fully digitized strategic function (Samman & Obaidly, 2024; Alan, 2023; Bag et al., 2022). Together, these domains illustrate how AI is not only an enabler, but a catalyst for the conceptual evolution of HRM.

BALANCING PROGRESS AND CONCERNS

Our findings reveal an important tension between operational excellence and ethical considerations in AI-HRM integration. The literature analysis presented in Table 3 demonstrates that most studies (n=266) highlight operational benefits, while fewer (n=33) address ethical concerns, privacy issues, and trust deficits in AI implementation. This imbalance suggests a potential research gap in critically examining the challenges associated with AI adoption in HRM.

Ethical issues emerge as a primary concern, with studies highlighting algorithmic bias, discrimination, and fairness concerns (Mori et al., 2024; Bankins et al., 2022; Prikshat et al., 2022). These concerns reflect broader societal discussions about AI ethics and emphasize the need for robust ethical frameworks to guide AI implementation in HRM contexts. Trust deficits constitute another significant challenge (Bankins et al., 2022; Park et al., 2021). This highlights a critical implementation challenge: even technically superior AI systems may face resistance if they fail to secure employee trust. Data privacy concerns focus on the handling of sensitive employee information, with studies indicating inadequate governance frameworks for AI-processed employee data (Khushk et al., 2024; Tsiskaridze et al., 2023).

Despite these concerns, operational excellence emerges as a major source of progress in AI-HRM integration. Studies report enhanced operational effi-

ciency (Stankevičiūtė, 2024), improved decision-making through data analytics (Kumar et al., 2024), more cost-effective HR operations (Alaghbari et al., 2024), and superior talent acquisition outcomes (Black & van Esch, 2020; Yu et al., 2023; Zheng et al., 2024).

The emergence of new skills and roles represents another important source of progress, as AI integration drives the development of new competencies among HR professionals. This skill development transforms HR professionals into strategic partners capable of aligning AI capabilities with organizational objectives.

THEORETICAL AND PRACTICAL IMPLICATIONS

Our findings significantly advance the understanding of AI's role in HRM. First, AI integration challenges the established theories by transforming traditional HRM functions – with exceptional accuracy in candidate evaluations reconceptualizing talent assessment expertise, and reduced processing times altering efficiency models. Second, emerging domains like Virtual HRM, Personalized HRM, and AI-enabled Green HRM extend HRM's conceptual boundaries, necessitating new theoretical frameworks to explain their relationship with traditional functions.

Third, the tension between operational excellence and ethical concerns reflects broader theoretical debates about technology in organizations, contrasting the utilitarian perspectives prioritizing outcomes against employee rights and dignity.

Practically, our findings provide compelling evidence for AI adoption in recruitment, performance management and compensation planning, while highlighting the implementation challenges. Organizations implementing AI in HRM should develop the following: (I) robust ethical frameworks; (II) transparent decision-making processes; (III) hybrid human-AI oversight models; (IV) comprehensive data governance policies; and (V) AI literacy programs for HR professionals.

The new functional domains offer practical opportunities: Virtual HRM provides frameworks for managing remote workforces, Personalized HRM enables tailored employee experiences, and AI-enabled Green HRM aligns practices with sustainability goals, potentially enhancing both environmental performance and employee engagement.

CONCLUSION AND FUTURE RESEARCH DIRECTIONS

This paper comprehensively examined the transformative role of AI across core HRM functions through three research questions. The findings affirm that AI not only enhances traditional HRM functions, but also facilitates the emergence of new domains such as Virtual HRM, Green HRM, and Personalized HRM. AI technologies like artificial neural networks and machine learning have increased operational efficiency and decision-making accuracy. However, relational HRM remains underexplored. AI's integration also introduces significant challenges, including ethical concerns related to algorithmic bias, fairness, and data privacy, as well as trust deficits and fears of job displacement. These issues highlight the need for human-centric approaches, supported by transparent governance, ethical frameworks, and comprehensive training to ensure responsible AI deployment. Achieving synergy between AI capabilities and human oversight is vital for protecting employee dignity and organizational integrity.

The study emphasizes the importance of ongoing research into underexplored functions and emerging domains to promote equitable and sustainable AI integration in HRM. There is a critical need to explore AI's application in lesser-studied areas such as employee relations, predictive compensation strategies, and equitable pay systems (Rabenu & Baruch, 2024; Singh et al., 2024), as well as its role in enhancing employee engagement via sentiment analysis and chatbot interfaces (Majumder & Mondal, 2021; Lee & Song, 2024). Emerging areas like Virtual, Green, and Personalized HRM offer opportunities to investigate AI-driven sustainability and personalized employee experiences (Depoo & Hermida, 2024; Abid et al., 2024; Huang et al., 2023; Shayegan et al., 2023). Longitudinal studies are essential to assess AI's sustained impact on trust, organizational performance, and employee well-being (Tairov et al., 2024; Bankins et al., 2022). Further research should also focus on building ethical frameworks, understanding cultural influences on AI adoption, and developing hybrid models that integrate AI efficiency with human judgment (Manroop et al., 2024; Bar-Gil et al., 2024; Roppelt et al., 2024; Kononova et al., 2022; Andrieux et al., 2024).

We identify several promising directions that future research should explore, such as longitudinal studies examining the long-term effects of AI adoption on performance and employee adaptation; AI applications in underexplored areas like employee relations and communication; sentiment analysis and AI tools for enhancing organizational culture; practical ethical frameworks addressing bias, privacy, and fairness concerns; optimal human-AI col-

laboration models across different contexts and cultures; effective mechanisms for building trust in AI-driven HR systems; and the evolution and integration of emerging domains (Virtual, Personalized, and Green HRM) with the existing frameworks.

This research is limited by its reliance on published academic literature, potentially overlooking the industry insights and unpublished case studies. While capturing recent developments, the 2020-2024 timeframe may not reflect AI's complete evolution in HRM. Despite systematic protocols, studies using alternative terminology might have been missed. The analytical imbalance across HRM functions and exclusion of non-English publications limits the comprehensive understanding and cultural diversity in the findings, potentially missing important contextual variations in AI implementation.

In conclusion, our systematic review reveals that AI is fundamentally transforming HRM functions, creating new functional domains, and generating both significant progress and important concerns. The uneven distribution of research attention across different HRM functions and the imbalance between progress and concern narratives suggest important gaps in the current understanding. Addressing these gaps through future research will be essential for developing more comprehensive theoretical frameworks and practical guidelines for AI implementation in HRM contexts.

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DIGITAL ECONOMY FROM THE STUDENTS' PERSPECTIVE

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This paper explores the students' perceptions of the digital economy, examining whether they see it as a driver of socio-economic progress or as a source of confusion and misunderstanding, particularly among younger generations. The study analyzes the results of a survey conducted among the students of the Faculty of Economics & Business, University of Zagreb, assessing their awareness, opinions, and readiness to engage with the digital economy. The students' concern with how they interact, their exposure to current trends in the digital labor market, as well as the systematic, economic changes brought about by technology are some of the research questions in this study. The study also covers concerns in regard to automation and displacement of employment, along with the emergence of ethical concerns regarding privacy of information and the impact of artificial intelligence evolution. This study will, therefore, fill important gaps in the knowledge and preparedness of students that are required to be able to transform economically by covering all such issues. In addition, gender, school education, disciplines, and technology accessibility have been the focus of the analysis of differences in the attitudes of the various students surveyed. For example, the results suggest that there may be some differences in the way male and female students consider the potential drawbacks and benefits of automation. In the same vein, students having the most advanced digital devices are reported to be more self-assured regarding the usage of digital media. This adds some complexity to how demographic characteristics influence the practice and adoption of different practices within the digital economy. The results showed that although

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most of the students accept that the new economy encompasses numerous aspects of nurturing creativity, economic development and worldwide integration, a portion of the student population considers themselves to be ill-prepared for the intricacies of the problems and the risk involved. Missing critical digital skills, poor understanding of the elements of digital business models, and lack of information on the ethical aspects of the models all indicate the presence of specific educational gaps which need to be filled. The research will go further in contributing to the debate on the economics of decoupling by analyzing how globalization can occur in the digital era through the means of education. These insights could help inform policy formulation by enabling educators and businesses to make relevant changes that will allow the youth to embrace all the opportunities presented by the digital economy.

Keywords: *digital economy, education, sustainability, students, economic decoupling*

JEL classification: *O33, J13, J24, I23*

1. INTRODUCTION

Are we prepared for the digital economy transition? In the current age of rapid technological advancement, the digital economy has emerged as a dynamic and transformative force reshaping how we live, learn, and work (Tapscott, 2015). For today's youth – especially university students – this environment presents vast opportunities, but also significant challenges, as they navigate the increasingly digital career paths, social networks, and learning models. The notion of a “decoupling economy” adds another dimension to this landscape: while some sectors are experiencing exponential growth driven by digital innovation, others are facing stagnation or decline, creating disparities that are particularly salient for younger generations entering the workforce (Chang, 2021). Against this backdrop, youth's perspectives on the digital economy are becoming critical for policymakers, educators, and businesses that are seeking to foster inclusive growth and equip students with the right skills to thrive.

The “digital native” generation is unique: many students have grown up with constant internet access, ubiquitous mobile devices, and social media platforms, yet may still lack structured, in-depth training to harness digital tools effectively (OECD, 2019). In higher education settings, some students struggle to align academic learning with the requirements of a fast-paced digital labor

market. Challenges range from skills mismatches to uncertainties about long-term career pathways. OECD reports (2014) indicate that basic knowledge and skills are no longer sufficient for individuals or the society to thrive. Beyond cognitive abilities, non-cognitive skills – such as communication and social interaction – have become vital. Similarly, “The Learning Curve” (Pearson and The Economist Intelligence Unit, 2012) emphasizes a range of essential 21st-century skills, including digital literacy (Spajić Vrkaš & Potočnik, 2017). Moreover, in the context of decoupling economies, the gap between digitally thriving industries – such as software development, digital marketing, or e-commerce – and traditional sectors – like manufacturing or agriculture – is widening, thereby affecting the strategic choices the youth make regarding work and further education (McKinsey Global Institute, 2021). It is crucial to understand how university students perceive these shifts and prepare for them as they chart their future trajectories.

The existing literature has explored numerous aspects of the digital economy, including its impact on labor market structures (Susskind & Susskind, 2015), skill development needs (Brynjolfsson & McAfee, 2016), and socio-economic inequalities (European Commission, 2020). The consensus is clear: the digital economy is a powerful engine for innovation and economic growth, capable of generating new forms of work and novel business models (Tapscott, 2015). Research on youth perspectives specifically has also shed light on the diversity of digital skills across different socio-economic backgrounds, highlighting disparities in access to high-quality education and technology (OECD, 2019).

However, a gap remains regarding how young people internalize and respond to the notion of a decoupling economy, where robust digital sectors exist side by side with struggling traditional industries. The existing studies tend to focus on macro-level analyses, overlooking the nuanced individual experiences, fears, and aspirations of students who are on the cusp of entering the workforce (Chang, 2021). Moreover, while researchers have examined digital literacy among youth, fewer have investigated the holistic set of challenges they face – from perceived skill gaps to information overload on social platforms, and from concerns about employability to questions about how higher education aligns with future labor market demands. Thus, there is a need for deeper empirical insight into student attitudes, especially in educational contexts that are rapidly digitizing, but may lack the resources to fully support digital upskilling.

This paper provides a quantitative analysis of survey data, offering a multi-layered perspective on youth experiences and aspirations in the digital economy. The ultimate objective is to provide evidence-based recommendations

for higher education institutions, policymakers, and industry stakeholders to better align skill development programs and employment opportunities with the demands of a rapidly digitalizing world.

2. METHODS¹

This study investigates graduate students' perceptions of the digital economy, focusing on awareness, perceived impacts, and digital skills. Data were collected through a structured online survey administered to students of the Faculty of Economics & Business at the University of Zagreb. The survey was designed to ensure accessibility and broad participation, leveraging the university's Google Classroom platform to reach students across different study programs. Over a two-week period, a total of 325 valid responses were gathered, providing a comprehensive dataset for analysis.

2.1. *SAMPLE CHARACTERISTICS*

This study surveyed 325 students from the Faculty of Economics & Business, University of Zagreb. The sample included 110 males (33.8%) and 215 females (66.2%). The average age of the respondents was 21 years (mean: 20.99, median: 20), with ages ranging from 18 to 25 years. Students were primarily enrolled in various economics and business-related disciplines, with representation from multiple study programs. The majority of the students were in their second or third year of study.

2.2. *SURVEY DESIGN*

The survey consisted of 20 questions divided into two main sections:

- a) **Demographic and Background Information:** Variables in this section included gender, field of study, work status (student contracts), and

¹ Acknowledgment of LLM Usage (AI): The author acknowledges the use of large language models (LLMs), during the preparation of this paper. These tools were employed to facilitate literature review, generate initial drafts of sections, refine academic language, and improve overall clarity and coherence of the text. The final responsibility for the content, analysis, and conclusions drawn in this paper rests solely with the author.

high school background. These variables provided a foundation for subgroup analyses and allowed for an exploration of how background factors influence perceptions and readiness for the digital economy.

- b) **Digital Economy Perceptions and Readiness:** This section explored students' awareness of the digital economy, their attitudes toward its impacts on the society and labor markets, and their opinions on the skills necessary to succeed in the evolving digital landscape.

The survey questions were designed so as to capture both categorical and ordinal responses, enabling a detailed analysis of the patterns and relationships between the variables. Descriptive statistics, including frequencies, percentages, and summary measures, were calculated to provide an overview of the sample characteristics and general trends in digital economy awareness, perceived impacts, and the importance of digital skills. Key demographic variables such as gender, field of study, and high school type were analyzed in order to understand the composition of the sample and highlight subgroup differences. Inferential methods were employed in order to examine the relationships and test hypotheses between key variables.

While the survey collected a wide range of data, not all variables were included in the analysis. The study focused specifically on three areas of interest:

- a) **Digital Economy Awareness:** Understanding the students' familiarity with the concept of the digital economy and its activities.
- b) **Perceived Impacts:** Assessing the students' views on the socio-economic effects of the digital economy, particularly on traditional labor markets.
- c) **Digital Skills:** Evaluating the perceived importance of advanced digital skills and the students' readiness to adapt to digital economy demands.

2.3. LIMITATIONS

The study relies on a sample from a single faculty - Faculty of Economics & Business, University of Zagreb, which does not represent the broader student population in terms of demographics, academic fields, or cultural diversity. Also, a general survey limitation exists – the data rely on students' self-reported attitudes and perceptions which may be influenced by social desirability bias (answering what they think is expected) or inaccurate self-assessment.

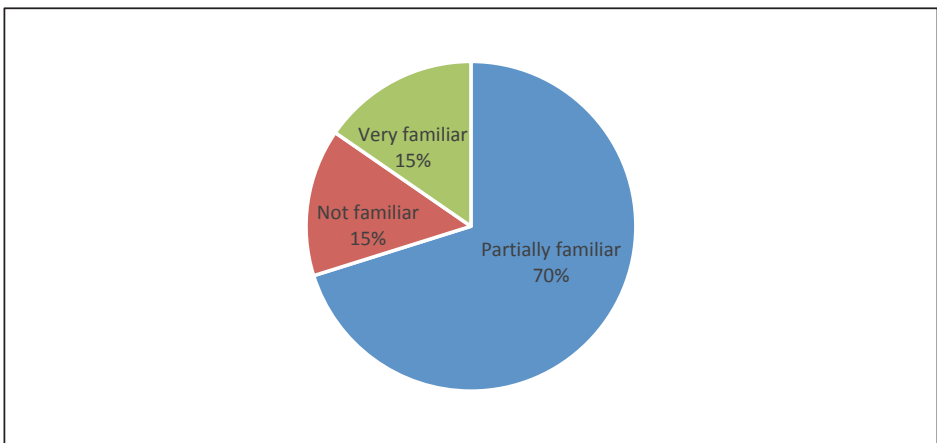
Future research should expand the research sample to other institutions and areas.

3. RESULTS AND DISCUSSION

3.1. GENERAL AWARENESS AND PERCEIVED IMPACTS - DESCRIPTIVE ANALYSIS

Awareness is the starting point for any shift towards new economic models. Understanding the level of awareness among students is critical to identifying whether they are ready to embrace the digital economy. In the context of this paper, it can be analyzed so as to see how awareness influences their perception of decoupling traditional industries from digital economies. If awareness is low, it may indicate that students are unprepared for the transition to a digital economy, potentially hindering the decoupling process. Conversely, high awareness might signal readiness to adopt digital practices that align with sustainable development.

Figure 3. How familiar are you with the concept of digital economy? - survey results

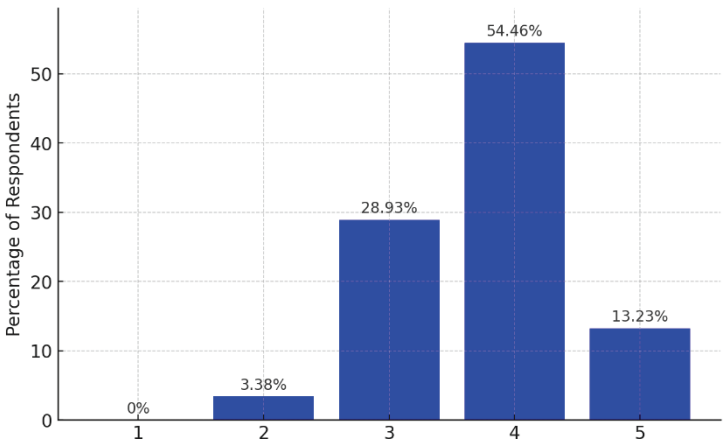


Source: survey data

A survey of students revealed that, while the majority (70%) possess a basic understanding of the digital economy, their knowledge appears to lack depth and practical application. This suggests a potential gap between theoretical understanding and real-world experience, highlighting the need for educational interventions that incorporate practical exercises and more nuanced explorations of the subject. Concerningly, a significant minority (14%) reported

being completely unfamiliar with the concept of the digital economy. This underscores the importance of providing introductory educational resources and courses covering fundamental digital business models and technologies to this segment of the student population. It should be noted that the students were provided with a definition of the digital economy following the initial familiarity question².

Figure 4. What impact do you think further development of the digital economy has on the overall socio-economic development? - survey results (%) on a Likert scale (1- extremely negative, 5- extremely positive)



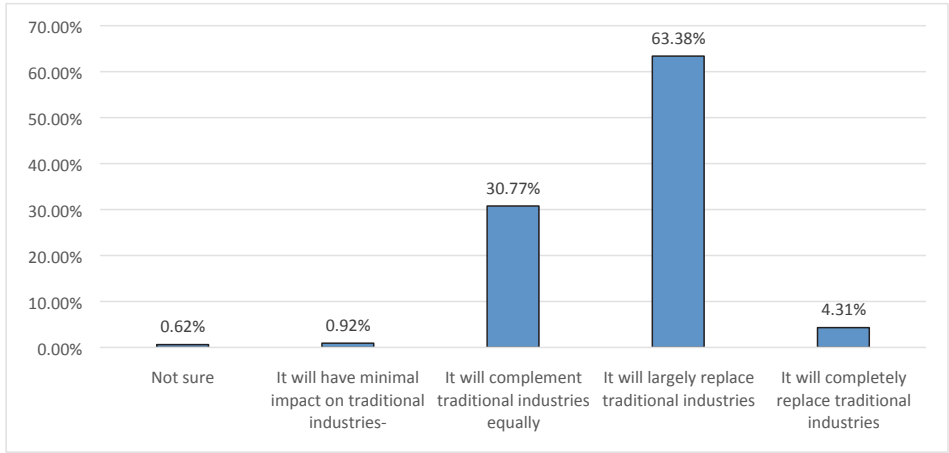
Source: survey data

The survey results regarding the perceived impact of the digital economy on socio-economic development suggest a predominantly optimistic outlook among the respondents. Specifically, no participant viewed the digital economy as having an “extremely negative” influence (0% for rating 1), while only a small minority (3.38%) expressed a slightly negative stance (rating 2). In contrast, most students (54.46%) positively rated the digital economy’s impact, and an additional 13.23% considered the potential effects to be “extremely positive”.

² After the introductory question about knowledge of the digital economy (Figure 3), it was compared with the traditional one and defined. **Digital economy:** Activities that rely on digital technologies, such as e-commerce, digital platforms, artificial intelligence, and data-driven industries. **Traditional economy:** Conventional economic sectors, such as manufacturing, agriculture, and physical retail, etc.

This optimistic perception among students aligns with a broader trend observed in various studies, which highlight the digital economy’s potential to enhance productivity and foster innovation across multiple sectors. For instance, research indicates that the integration of digital technologies can significantly increase production efficiency and create new job opportunities, leading to sustainable economic growth (Mottaeva et al., 2023). However, it is essential to consider that this rapid transformation may also exacerbate skill gaps within the workforce, as certain individuals may find themselves ill-equipped to navigate an increasingly digital landscape.

Figure 5. To what extent do you think development of the digital economy will affect the traditional industry? – survey results

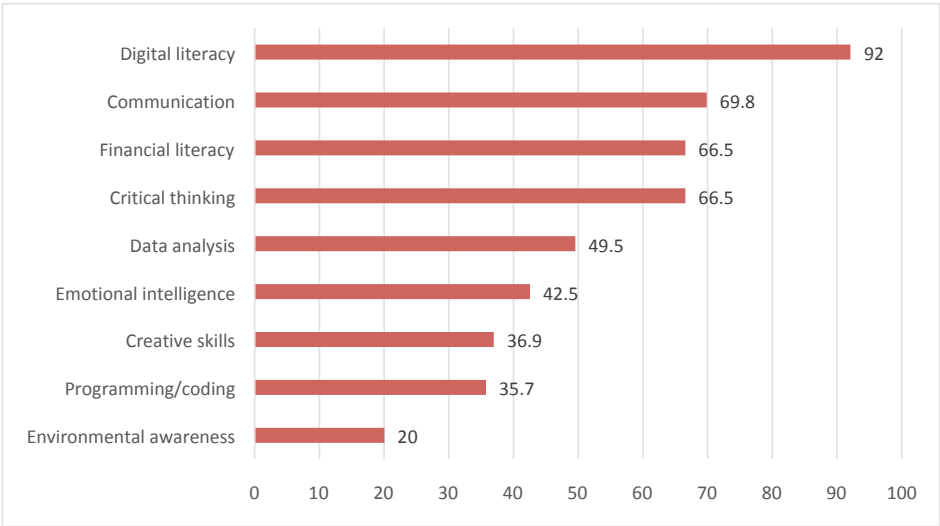


Source: survey data

The data presented in Figure 5 illustrates the students’ perceptions regarding the impact of the digital economy on traditional industries. A significant proportion of respondents (63.38%) anticipate that the digital economy will largely replace traditional industries, indicating a strong expectation of substantial disruption. Meanwhile, 30.77% of the students envision an equal complementarity between the digital and traditional sectors, implying a balanced integration of technological advancements with the existing systems. Only a minority foresee either minimal impact (0.92%) or a complete replacement of traditional industries by digital technologies (4.31%). These responses collectively point to a prevailing expectation that the digital economy will drive profound transformations across traditional sectors, albeit with varying degrees of integration in certain contexts.

The transformative influence of digitalization on traditional industries aligns closely with the decoupling thesis (particularly within the ICED Conference hypothesis framework). Student perspectives provide valuable insights into the potential of digital innovation to reduce reliance on resource-intensive industries, fostering both sustainability and economic growth. The analysis sheds light on the extent to which digital transitions are perceived as catalysts for minimizing environmental impact while simultaneously driving economic development. These insights may also guide the formulation of policies aimed at overcoming resistance to change and facilitating smoother integration of digital technologies into traditional industrial frameworks. According to these findings, the youth population should not represent an obstacle to implementing structural changes in the education system and labor market towards digitalization.

Figure 6. *In your opinion, which of the skills will be very important for your future? –multiple option answers (% of all respondents)*



Source: survey data

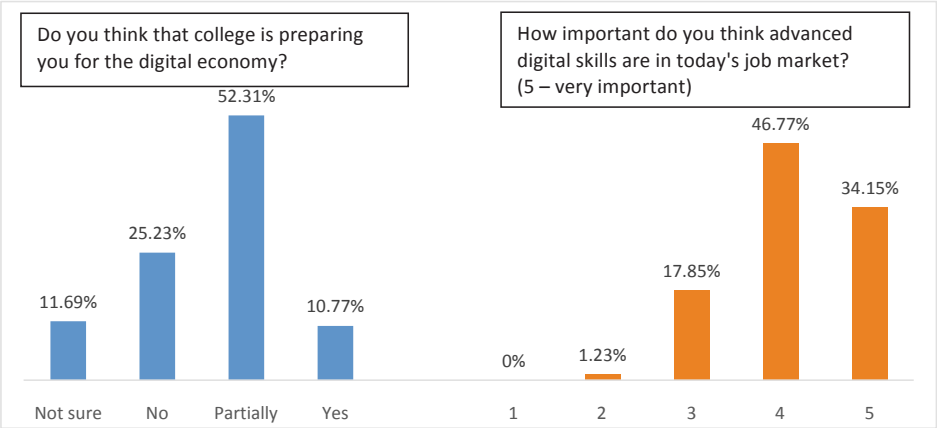
The data indicates that digital literacy stands out as the most important skill, with 92% of the respondents identifying it as essential (Figure 6). This underscores a clear recognition among the students regarding the critical role that digital competency will play in future workplaces and societal dynamics. This emphasis on digital literacy not only reflects the students’ awareness of its importance, but also highlights the urgent need for all educational institutions,

regardless of their field of study, to adapt their curricula to the demands of the digital economy. The integration of digital literacy into education is essential for developing 21st-century skills, improving employability, and enhancing academic performance, as it aligns with the demands of a rapidly evolving digital landscape (Huzooree et al., 2024).

As the labor market evolves, universities are increasingly tasked with equipping students with relevant ICT skills that align with industry demands, ensuring they remain competitive in a rapidly changing environment. Moreover, fostering digital literacy can enhance critical thinking and problem-solving abilities, which are essential for navigating complex work scenarios (Vodá et al., 2022). Consequently, integrating hands-on experiences with technology into academic programs may prove invaluable, as it allows students to cultivate these competencies while simultaneously engaging with real-world applications of their learning.

Croatian youth rely heavily on technology, which shapes their social integration and job prospects by providing them with stronger computer skills compared to the older generations (Potočnik, 2007). This heightened digital competence, especially in communication and entertainment, highlights the importance of cultivating digital literacy. Young people’s preference for specific online content and social networks underscores the need for broader educational applications of the Internet, as well as a more critical approach to evaluating online information (Gvozdanović et al., 2019).

Figure 7. *Perceived adequacy of study programs in meeting the growing demand for digital skills – survey results*



Source: survey data

Graph 7 highlights the students' perceptions of the adequacy of study programs in meeting the growing demand for digital skills. When asked if their college is preparing them for the digital economy, the majority of students (52.31%) felt "Partially" prepared, while 25.23% indicated "No" and 11.69% were "Not sure". Only 10.77% of the respondents believed that their study program fully prepares them for the digital economy.

In contrast, when evaluating the importance of advanced digital skills in today's job market, most respondents (46.77%) rated it as "Very important", with another 34.15% selecting "Important". Almost no respondents considered these skills unimportant (1.23% rated it "2" and none selected "1"). These results suggest a perceived misalignment between the growing demand for digital skills and the adequacy of current study programs in preparing students for the digital economy.

This perceived inadequacy in educational programs raises critical questions about the alignment of curricula with industry needs, particularly as technological advancements continue to reshape job requirements. For instance, many institutions struggle to integrate digital transformation effectively into their teaching practices due to outdated infrastructures and a lack of strategic planning (Mondragon-Estrada et al., 2023; Pettersson, 2021). As businesses increasingly prioritize digital capabilities, the gap between education and employment could hinder not only individual career prospects, but also broader economic competitiveness. Furthermore, enhancing collaboration between educational institutions and industries may provide students with practical experiences that bridge this skills gap, fostering a workforce better equipped for the demands of the digital economy.

3.2. GENDER DIFFERENCES IN DIGITAL ECONOMY PERCEPTIONS

The analysis reveals significant gender differences in the students' perceptions of the digital economy and its implications. The Mann-Whitney U test indicated that males reported significantly higher familiarity with the digital economy compared to females ($z = -2.146$, $p = 0.0318$). Similarly, an ordinal logistic regression confirmed this finding, showing that males had 1.744 times higher odds of being in a higher category of familiarity than females (OR = 1.744, 95% CI: 1.053–2.889, $p = 0.031$).

Moreover, a Chi-square test examining the perceived impact of the digital economy on traditional labor markets demonstrated a significant association between gender and perceptions ($\chi^2(3) = 14.30$, $p = 0.003$). Females were more

likely to believe the digital economy will completely replace traditional industries, whereas males were more likely to perceive minimal impact.

In examining the relationship between gender and perceptions of faculty preparedness for the digital economy, test results were not statistically significant, $\chi^2(3, N = 325) = 2.17, p = 0.538$, suggesting no significant association between gender and perceptions. The majority of both male and female respondents felt their college was “Partially” preparing them for the digital economy (50% of females, 50% of males).

3.3. EDUCATIONAL BACKGROUND (HIGH SCHOOL)³

The results suggest that high school background has a limited impact on digital economy awareness. The Chi-square test indicated no overall significant association, reflecting that awareness levels are similarly distributed across all high school types. However, the Ordinal Logistic Regression revealed a more nuanced finding: students from “Other” high schools demonstrate significantly lower awareness compared to those from economics high schools, likely due to curriculum differences or less exposure to digital economy-related topics. Contrary to expectations, students from grammar schools (“gymnasium” in Croatia) and mathematics high schools show no significant difference in awareness compared to economics school students.

3.4. PERCEIVED PROGRAM ADEQUACY FOR DIGITAL SKILLS

The analysis reveals a weak, but statistically significant, positive correlation between the students’ familiarity with the digital economy and their perception of the adequacy of the study program in preparing them for it (Spearman’s rank correlation; $\rho = 0.13, p = 0.019$). This suggests that students who are more familiar with the digital economy tend to perceive their study program as slightly more effective in equipping them with the necessary digital skills. However, these results should be interpreted with caution, as students’ expectations of the skills acquired from studying are generally influenced by their understanding of the digital economy, which may vary significantly. The

³ Education variable represents the type of high school respondents attended, categorized into four groups: 1 = Economics School, 2 = Grammar School, 3 = Mathematics High School, and 4 = Other.

abstract nature of the term “digital economy” likely contributes to differing expectations and perceptions among students.

CONCLUSION

This study provides valuable insights into graduate students’ perceptions of the digital economy, focusing on awareness, perceived impacts, and the importance of digital skills. The findings highlight that while students generally acknowledge the transformative potential of the digital economy, there are notable variations in their awareness and preparedness based on educational background and personal experiences. These insights underscore the necessity for educational institutions, regardless of their field of study, to enhance digital literacy programs, ensuring that all students are equipped with the skills needed to thrive in an increasingly digital world.

Findings can be contextualized within the decoupling thesis, which posits that economies are transitioning from traditional industrial structures toward more digitally driven systems, and this could be an opportunity to leverage the development of technologies that foster inclusive growth and bridge the digital divide.

In order to facilitate a smoother transition to the digital economy, policy-makers should prioritize integrating digital economy topics across educational curricula, fostering collaboration between academia and industry, promoting lifelong learning, supporting research and innovation, ensuring an inclusive digital transformation, and raising public awareness about the changing economic landscape.

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DIGITAL CUSTOMER JOURNEY MAPPING IN RETAIL

Steliana VASILEVA*

Customer experience (CX) has gained significant importance in the field of consumer behaviour, primarily because of how it influences the development of long-term customer relationships. The next stage in the study of CX involves new contexts represented by the digital channels used by retailers. Advanced technologies, such as Artificial intelligence (AI), big data, and IoT (Internet of things), present both opportunities and challenges for retailers because they require improvements both in the processes and in businesses. Despite the above mentioned, there is no clear map for transforming business models that can fully utilize the available and emerging digital technologies. Mapping and enhancing the customer journey (CJ) is crucial for improving CX. While customer journey mapping is widely adopted in retail, the topic of creating a (digital) customer journey map ((D)CJM) in retail, has received relatively modest coverage in the academic literature. Many of the existing articles (both by academics and practitioners in the field) that discuss customer journey mapping still question the best ways to model the CJ. The purpose of this paper is to address some of these issues by developing a conceptual framework, based on the theories that explore customer journey mapping, and retail and digital technologies (and how they are influencing consumer behaviour). In the study, the author attempts to select papers that extend and develop theories, and a model that can also serve for future research on the subject. In particular, this paper offers a solution to the cumbersome complexity of customer journey mapping by proposing a conceptual model for customer journey mapping in the retail context. The results obtained by using (digital) CJMs can help retailers gain a better understanding

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of consumers' decision-making progress in online, omnichannel environments, as well as optimize their channel structures. In other words, digital customer journey mapping can assist retailers in understanding what their customers desire and can be helpful in identifying (digital) possibilities in the (retail) industry.

Keywords: *(Digital) customer journey, customer experience, customer journey mapping, touchpoints*

JEL classification: *M30, M31.*

INTRODUCTION

Digitalization is bringing significant innovations to retail and has already captured the attention of both marketing academics and practitioners in the field. The existing studies, however, are fragmented and related to specific aspects of digitalization-driven retail business (e.g., Bollweg, Lackes, Siepermann and Weber 2019, 2020). Customer journey mapping and understanding the role of CX at each stage of the journey are, therefore, of great importance for retailers aiming to survive in today's technology intensive environment.

Retailers can choose from a variety of online marketing channels in order to reach consumers on the Internet, and potential customers often use a wide range of channels during their CJ. Early research on the subject focused on the effectiveness of single channels (display and search, for example) in isolation, whereas other studies (Papadimitriou et al., 2011; Abhishek, Fader and Hosanagar, 2012; Nottorf, 2013; Lewis and Nguyen, 2014; Xu, Duan and Whinston, 2014; Kireyev, Pauwels and Gupta, 2016) with an omnichannel focus looked at the interaction of several selected channels (with an emphasis on display and search). The actual number of online marketing channels that retailers use is greater than in the previously mentioned studies on the topic, and European marketers (Teradata Corporation, 2013) announced using an average of seven channels in parallel back in 2013. Although there are some exceptions (e.g., Anderl et al., 2014; Li and Kannan, 2014), scarce research exists on the full spectrum of digital marketing channels that the retailers utilize. Thus, there is a pressing need for a research perspective that will make sense of the current literature, and that will provide a deeper understanding of areas which require further research in relation to digitalization-enabled retail business (Paul and Rosenbaum, 2020). Furthermore, the increasing complexity of digital technologies nowadays – analytics, mobility, social networks, cloud

computing and the IoT – still represents a challenge for retailers, and is forcing them to transform.

Although many articles discuss customer journey mapping, both academics and practitioners in the field still question the best ways to model the CJ. It can be argued that some CJMs are critically flawed (Lemon and Verhoef, 2016), because they assume that all customers of an organization encounter the same touchpoints and view those touchpoints as equally important, while in reality, it is crucial for the mapping to be dynamic. Customer journey mapping is very complex due to the heterogeneity of all markets, including retail. Another thing that retailers should take into consideration is the fact that the same consumer may have a completely different CJ at different times because of different contexts. This means that most CJMs, unless they are dynamic and include context, can be misleading.

Considering the complex customer behaviour and CJs in omnichannel (digital) retail, *this paper aims to explore some critical aspects of the CJ, while defending the statement that the best way to take advantage of digitalization is to take a holistic, not a piecemeal, approach, and a key tool to achieve this is DCJ mapping.* In light of the abovementioned, the paper seeks to answer the following questions:

- 1) How does digitalization influence changes to the retail business? (The sub question, in the context of the study, is linked to digitalization-driven retail value creation and enhancement of the omnichannel customer experience, in particular.)
- 2) How do marketers interpret customer journey mapping (digitally)?

Specifically, the current paper is structured as follows: In the first section, theories in the field of digitalization and retail are discussed. The next two sections then describe customer journey mapping and the characteristics of (digital) CJMs (in retail). This is followed by a proposal for a conceptual model that visually maps the purchase stages and touchpoints. The main components of the model are presented and explained. The last section concludes the paper and provides an outlook. The findings of this study should provide an important academic contribution to pave the way for further use of CJMs, as the proposed model helps retailers understand each step that the customer takes, from initial interest to the post-purchase stage, allowing for strategic improvements that lead to a better customer shopping experience.

ABOUT THE DIGITALIZATION AND RETAIL BUSINESS

The current view of digitalization often incorporates examples of diverse technologies – IoT, virtual reality, AI-powered robots (Hoyer et al., 2020), augmented reality (Nikhashemi, Knight, Nusair & Liat, 2021) – that the retail industry is accepting. Despite the positive impacts of digitalization, such as cost reduction and efficiency, some retailers are not able to benefit from the rapid technological development and are missing out on omnichannel opportunities. Although retailers are trying to deliver a consistent CX across different channels, the existing business models are not completely prepared for its provision (Gavrila & de Lucas Ancillo, 2021).

Notwithstanding the above-mentioned benefits that digitalization provides for retailers, it also has negative aspects, such as the creation of new competitors. Retailers face competition from online second-hand shopping sites, online consumer sites and Facebook Marketplace (Padmavathy et al., 2019). Apart from this, retailers encounter a powerful competitive environment from ecommerce champions like Amazon, lack of shopper experience, lack of omnichannel integration (McKinsey & Company, 2014). Taking into account the rapid pace of globalization, technology, and the social, cultural and political changes, as well as the changing family structures, immigration patterns and global trade wars, marketers need to explore new theoretical perspectives, different conceptual models, processes and issues related to the contemporary retail industry (Das and Varshneya, 2017; Paul et al., 2016; Paul and Sahadev, 2016).

Digital technologies have improved CX both online and in brick-and-mortar stores (Battisti and Brem, 2020; Grewal et al., 2019; Hoyer et al., 2020). In order to bring the digital and physical stores closer together, Jocevski (2020) has identified five areas of possibility for innovation – collaborations, in-store technology, data analytics, the role of sales associates, and leveraging a mobile channel. Such omnichannel strategies, enabled by digitalization, have given customers multiple points to order, collect, or return branded products. Meanwhile, the challenge for retailers is to integrate CX throughout all the different channels (Sun, Yang, Shen and Wang, 2020).

BACKGROUND AND UNDERSTANDING OF THE CUSTOMER JOURNEY MAP

The retail industry has transformed from incorporating traditional independent small stores to large stores and malls (El-Adly and Eid, 2016; Paul et al., 2016), and ultimately the new-generation oriented channels that we have today. Consumers already engage and interact with retailers and their brands through a multitude of online channels and touchpoints during the CJ. The CJM is, therefore, a tool for understanding the CJ as it depicts the chronological flow of touchpoints that customers go through while interacting with a product or service (Moon et al., 2016; Heuchert, 2019), from pre- to post-purchase stages (Følstad, Kvale and Practice, 2018; Rosenbaum, Otalora and Ramírez, 2017).

Nowadays, the CJM is one of the most widely used tools, which helps companies understand how their customers interact with their brands through touchpoints, how the retailer is perceived and how the company would like its customers experiences to be perceived (Nenonen et al., 2008). When used well, customer journey mapping can augment traditional approaches to customer insights research and evaluation, and bring initiatives closer to their customers (Andrews and Eade, 2013). A CJM contains at least one journey, which is a typical sequence of touchpoints followed by a customer. According to Følstad et al. (2013) the following *two types of CJMs exist*:

- 1) *the expected journey* – represents anticipated journey(s) – it is designed to describe what an ideal journey would look like (Andrews and Eade, 2013) and identifies the opportunities for novel services (Moon, Han, Chun and Hong, 2016), or is employed as a diagnostic tool (Stickdorn, Schneider, Andrews and Lawrence, 2011);
- 2) *the actual journey* – describes how the journey was “really” experienced by the customers, finds the existing customers’ problems or needs (Andrews and Eade, 2013; Dove, Reinach and Kwan, 2016; Moon, Han, Chun and Hong, 2016; Nakatani and Sato, 2013), or presents the consumption of services by the customers (Marquez, Downey and Clement, 2015).

In the omnichannel context, the CJM is basically a visual representation of the sequence of touchpoints that the customers encounter throughout their interaction with a company (Lemon and Verhoef, 2016; Rosenbaum et al., 2016) and with the online or digital experience, retail experience, service, or a combination of the aforementioned (Følstad et al., 2018). The more key events there are within a CJ, the more it is necessary for a company to adopt the customer journey mapping technique (Heuchert, 2019).

THE (DIGITAL) CUSTOMER JOURNEY MAPPING PROCESS

The author of the paper defines digital CJ as the steps that a modern consumer takes on their path to conversion, including every touchpoint from the initial awareness stage to the post-purchase support. The goal of retailers in mapping CJs is to remove obstacles and make the process efficient and intuitive. By taking the customer's perspective, companies can better understand the decision-making process and the experience of their consumers (Moon et al., 2016). This knowledge allows retailers to create a CJM – a strategic document that is usually created either for a fictional persona that represents a customer segment or for specific customers (Heuchert, 2019). A CJM can include not only the main events of the journey, but also emotional indicators (Halvorsrud et al., 2016). It literally outlines the best path for a typical CJ.

Customer journey mapping is usually presented as part of the research phase of the design process. This allows for the gathering of all events and aspects within a customer's journey in a single document or “organizational map”. This approach is often referred to as mapping (Crosier and Handford, 2012; Zomerdijk and Voss, 2010). However, some researchers do not use this term, but rather refer to this type of activity as documentation or assessment of CJs or journey-based audits (Clark, 1993).

Regardless of the specific terms used, customer journey mapping is a way to visualize the CX and the way customers interact with a brand. Before retailers start creating their CJMs and examining them for flaws, it is important to understand the “how and why”, because the more seamless the experience they can create, the better the CX will be. In this way, customer journey mapping makes it easier to analyse the customers' experience and identify the improvements that need to be made across all touchpoints (Moon et al., 2016; Rosenbaum et al., 2017).

CONCEPTUAL MODEL

CJMs can follow different structures and models. In order for the retailers to better understand how consumers navigate the retail environment (come across, switch between, and integrate various digital touchpoints in their purchase decisions), why they act the way they do, and consequently connect those touchpoints to what they are looking for, customer journey mapping has been adopted as the starting point, because it is important to provide retailers with insight into the customers' needs and the potential factors that directly or indi-

rectly impact their needs and behaviour when it comes to understanding their digital possibilities. The goal is to create a map (or several maps) that links the appropriate touchpoints and consumer experiences to each stage of the CJ. By crafting a detailed retail CJM, retailers can transform a chaotic shopping experience into a smooth journey from start to finish.

In terms of this paper, the proposed conceptual model for mapping the CJ in retail was inspired by the three-stage models (Lemon and Verhoef, 2016; Rudkowski et al., 2020) relating to CJ stages, and also by the touchpoints' classification framework presented by Baxendale et al. (2015). There is a close link to the stages within the consumer decision-making process and there appears to be some common agreement that CJs involve touchpoints. While there is a lack of agreement regarding CJ stages, Lemon and Verhoef (2016) and Rudkowski et al. (2020) are consistent with the definition of the three stages of pre-purchase, purchase and post-purchase. Shankar et al. (2016) also discuss three broad stages of before purchase, during purchase and after purchase – a shopping cycle. To quote Srinivasan et al. (2016: 442): “consumers on their path to purchase beginning with awareness and knowledge-building (cognition or thinking) to liking and preference (affective or feeling) to conviction and purchase (conation or doing)”. Similarly, the proposed model for digital customer journey mapping in retail, consists of a three-stage framework, from pre-purchase to post-purchase, which includes a set of channels and activities associated with these touchpoints and stages (Lemon and Verhoef, 2016). By including three stages in the digital CJ for retail, the process can provide clarity and consistency, and can be more manageable when researching the subject.

Nevertheless, the stages in the digital CJ for retail and their sequencing require further consideration. Alongside the traditional purchase process model, Edelman (2010) presents a version, based on the results of a study, in which instead of systematically narrowing the possible choices during the pre-purchase stage, consumers add and subtract companies and brands within a group of considered options. The stages of this journey (see Edelman, 2010) are as follows: consideration, evaluation, buying, enjoying, advocating, and bonding. Similarly, the following sub-stages – awareness, consideration, and also service and retention/loyalty/advocacy – have been added to the proposed model for digital CJ mapping in retail.

Additionally, while the stages have usually been presented linearly, in such way that consumers move from one stage to the next in order, there has been some discussion as Lemon and Verhoef (2016) describe the CJ as “iterative and dynamic”. In addition to recognizing this looping potential within the pre-

purchase, purchase, and post-purchase stages, it is also important to recognize that there can be nonlinearities, with consumers jumping between stages.

An analysis of articles exploring the topic (Kranzbuhler et al., 2019; De Keyser et al., 2015; Verhoef et al., 2021) identified that touchpoints should be considered at each of the aforementioned stages in the decision-making process, because customers often use multiple touchpoints throughout different stages of their journey. Considering the abovementioned, the digital CJ includes all the touchpoints that a customer has with a retailer across all online marketing channels (including prior to a potential purchase decision). Touchpoints include direct visits to the retailer’s website, clicks on online advertisements, and/or viewing of online advertisements that do not result in a click.

However, much like all CJs, retail CJs are not linear. Customers rarely proceed directly to the brand they want to purchase, choose one, and then complete their purchase – it is rather a process of wandering in and out of buying cycles throughout their daily lives. The DCJM in retail (see *Figure 1*) lists the possible company touchpoints that a customer may encounter during the exchange process.

Figure 1. Conceptual model for Digital Customer Journey Mapping



Source: Adapted from Lemon and Verhoef (2016) and Baxendale et al. (2015), and modified by the author of the paper for the purposes of the study.

The representation in *Figure 1* aims to summarize and illustrate a complete journey that a consumer might take with a retail brand. This provides a

representation of the customer's touchpoints in the retail industry, that is, the interactions a consumer has with a brand either from a website or in an app, indicating each digital channel that might be used at each stage during the CJ. The dynamic aspect of customers' journeys is represented in the model by the loops of arrows around each and all of the stages. In each stage, the consumer may experience cognitive, emotional, and/or behavioural responses that influence each stage and hold the potential to impact the other stages. This can be (in a linear way) considered traditionally, but it can also happen in a nonlinear way (in a looping manner) – the idea is that the different stages can provide an input to each other. The flexibility inherent to this DCJ mapping model allows for its application in a variety of shopping scenarios.

At the *pre-purchase stage*, consumers can not only perform internal and external information searches, but also refer to past retail brand experiences. This usually includes phases such as independent research of information and evaluation of options. In the proposed model (see *Figure 1*), the pre-purchase stage consists of *two sub-stages – awareness and consideration*. The CJ often starts with the *awareness* of a need rather than the discovery of a brand. At the awareness sub-stage, customers browse a company's online store, discover advertisements, and do initial research. During this stage, retailers have to strive to put their company's name in their customers' minds through (online) advertising, displays, social media (posts, ads and sponsored content on social media platforms such as Facebook, Instagram, X, Tik-Tok and LinkedIn), word-of-mouth recommendations or other forms of incentive and/or relevant content that can meet the customer's needs. Next, at the *consideration stage*, consumers compare prices, read product descriptions, and familiarize themselves with other customers' reviews. Consumers turn to trusted sources to give them the confidence they need in order to make their purchase. Thus, this sub-stage may involve visiting a retailer's website again, attending a webinar, and/or requesting a free trial.

The *purchase stage* is linked to activities such as selecting the desired brand, placing the order and paying for it (Lemon and Verhoef, 2016). Similarly, in the proposed model, customers can make purchases through a retailer's website or mobile app, select the desired brand, add it to their cart, place the order, select shipping options, and complete the checkout process.

Finally, at the *post-purchase stage*, customers test the acquired branded product, use it, decide whether or not to return it, think about repurchasing it in the future, and share their experience with it, among other activities (Lemon and Verhoef, 2016). Once the purchase is made, customers usually enter into a relationship with the retailer that can be described as an open loyalty cycle.

In the proposed conceptual model for mapping the DCJ in retail, the post-purchase stage consists of two sub-stages – *service* and *retention/loyalty/advocacy*. Another important aspect for the retailers to consider is that today's consumers undertake many repetitive journeys, which are less reductive in nature.

It is important to note that this framework is aligned with Halvorsrud et al.'s (2016) conceptualization of the CJ as a flow of chronologically staged touchpoints that customers go through while learning about a branded product, purchasing and interacting with the brand, and with the service provider. As can be seen in Figure 1, each of the encounters that occur across the purchase process is associated with certain activities and channels. The author of this paper also suggests that there may be nonlinearities in the process and consumers may jump from the pre- purchase to post-purchase stage. This may be due to the increased emphasis on trialability (e.g., Roggeveen, Grewal and Schweiger, 2020), and after the branded product is sampled in the pre-purchase stage, customers might jump to the post-purchase stage. Furthermore, advanced digital technologies (mobile, AI, IoT) can facilitate the fundamental nonlinear links that mark such journeys.

CONCLUSION

Creating a CJM is valuable to the extent that it is considered a tool for understanding the needs of a consumer at every stage of their journey. When retailers lose sight of the CJM as a means of understanding consumer needs, the points of the map become just a misleading analytical metric. The retailer's goal is to ensure that the customers' needs are met. Mapping the CJ is bigger than any single metric, and maintaining a level of strategic focus across the retail company requires the existence of a framework for the selection and analysis of marketing analytics.

Focusing on the digitalization of CJs in retail, the current paper provides a much-needed addition to the CJ management, and in part to the growing field of digitalization in marketing. Digitalization is widespread in today's markets. It drives change in general, which also includes retail CJs, and new insights in this area are valuable.

In order to provide more detailed insights, we have taken digitalization and retail business as the starting point of this paper, in addition to reviewing the background and understanding of the CJM and the process, and forwarding implications built upon the exploration of (digital) CJ in (retail), thus providing a more realistic and complete view of current omnichannel journeys.

The framework, suggested in this paper, is limited in several ways: 1) the proposed model is conceptual and has not yet been tested by practitioners and/or researchers in the field; 2) it is also assumed that a retailer has already invested considerable efforts in cultivating a marketing strategy; 3) it is also acknowledged that the retailer has determined its target segments, has tailored its brand offerings to the needs of those segments, and has properly communicated this information.

The proposed model is considered suitable for investigating digital CJs of various retail types. A suggestion for future studies is to start with quantitative research (based on interviews and/or focus groups) in order to collect numerical data, and then conduct content analyses. Mixed methods research (that combines qualitative and quantitative data) should be able to reveal industry-specific experiences and outcomes. Brick-and-mortar retailers might also consider the implementation and integration of the model, and thus make use of digital technologies on a larger scale so as to enhance the CX and CJ.

These limitations serve as input for future research. Both the testing and application of the proposed conceptual model for DCJ in retail, are essential for the future researchers in order to gain a better understanding of the CJ in the digital world.

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REGULATION OF MARKETS IN CRYPTO-ASSETS

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The Markets in Crypto-Assets Regulation entered into legal force on 29 June 2023. Together with Regulation (EU) 2022/858 (Distributed Ledger Technology Regulation) that came into legal force on 23 March 2023, it makes the European Union the first jurisdiction in the world to have a full regulatory framework on crypto-assets. Crypto-assets are defined as the digital representation of a value or of a right that is able to be transferred and stored electronically using distributed ledger technology (DLT) or similar technology. Such definition obviously departs from a technologically neutral regulatory approach. The European Union has an interest in developing and promoting transformative technologies in the financial sector, including the distributed ledger technology. It is expected that many applications of distributed ledger technology, including block chain technology, that have not yet been fully studied, will continue to result in new types of business activities and business models that, together with the crypto-asset sector itself, will lead to economic growth. The Markets in Crypto-Assets Regulation in general introduces licensing and registration regimes for major crypto-asset intermediaries such as crypto exchanges and custodians. Other major jurisdictions such as the United States have taken a more conservative stance with regard to the regulatory reform of their financial markets laws in the crypto area. The paper produces a normative overview of the Markets in Crypto-Assets Regulation in its subject matter, scope, definitions and categorisation of crypto-tokens in utility tokens, e-money tokens and asset-referenced tokens. A parallel analysis with a traditional regulation of financial markets in EU Law is provided, and interconnectedness is elaborated. The research focus is on

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the suitability of this new regulatory framework with the global nature of trade in crypto-assets. The paper detects the need for a global approach in the regulation of crypto-assets, possibly within the convention system of the United Nations, due to the borderless nature of the underlying technology.

Keywords: *Markets in Crypto-Assets Regulation, crypto, distributed ledger technology, regulation, EU Law*

JEL classification: *K24, K22, L86*

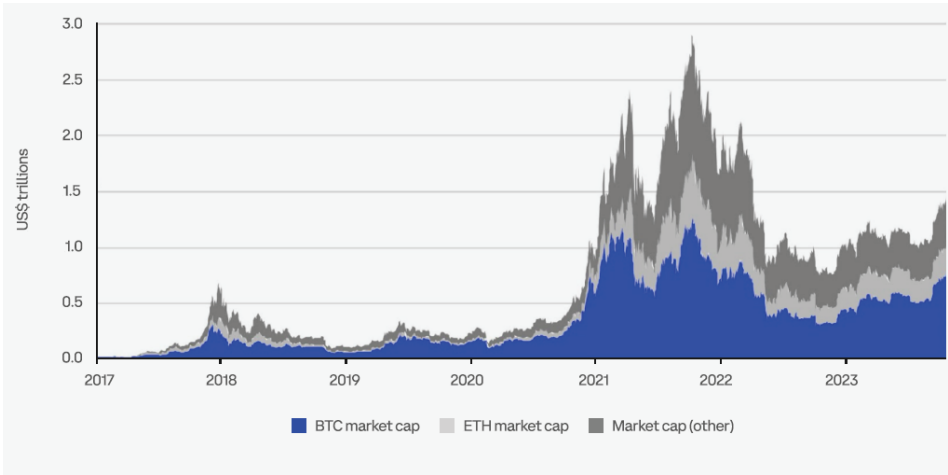
1. INTRODUCTION

The idea of a decentralized cryptocurrency named “bitcoin” was first introduced to the field of human knowledge in October 2008 when Satoshi Nakamoto published his (or her) famous paper on bitcoin (Nakamoto, 2008). In a remarkably short publication, Nakamoto proposed the establishment of a peer-to-peer network that would allow online payments with records that cannot be changed without redoing the established proof-of-work, all requiring minimal network structure. The proposed algorithm limited the bitcoin production (later called “mining” in the crypto community) to a finite amount at a certain point, and thus it can be categorised as scarcity-based Bitcoin (the algorithm limits a cap of 21 million bitcoins permitted to be mined). Nakamoto’s paper was actually not the first to conceptualise crypto currency. In his 1982 doctoral dissertation at the University of California, Berkeley computer science pioneer David Lee Chaum introduced a theoretical protocol for the blockchain protocol (Sherman, Javani, Zhang & Golaszewski, 2019). At about the same time, the first framework for electronic cash was conceptualised by David Chaum (Chaum, 1983). Since this early groundbreaking development, there have been several proposals for the establishment of cryptocurrencies before Nakamoto’s paper. A good example is a cryptocurrency proposed by a computer scientist Hal Finney in 2004 (Sherman et al., 2019), but not a single one of them has been implemented due to the various shortcomings like lack of vulnerability to attacks and protection against double spending, and the need for centralised control. Other notable examples of pre-bitcoin proposals include hashcash and bitgold. Bitcoin was implemented as an open source code in January 2009 and it quickly became the world’s first usable cryptocurrency.

Since then, we have seen an enormous expansion of economic activity based on cryptocurrencies, and a large number of new cryptocurrencies, usu-

ally called “altcoins” upon their first emergence on the market. The financial regulatory body of the United Kingdom, the Financial Conduct Authority (FCA), estimates that there were more than 20,000.00 different

Graph 1: Total crypto market capitalization at 1.5 trillion US dollars



Source: Duong, Han & Meadows, 2024

cryptocurrencies in 2023. This number is a very conservative estimation and is undoubtedly higher in the years 2024 and 2025. Total market capitalization of the entire global crypto market surpassed 1 trillion US dollars in 2021 according to the data from Coinbase (Duong, Han & Meadows, 2024), one of the biggest cryptocurrency exchange platforms, and it currently sits at 3.46 trillion US dollars as at January 2025. Bitcoin remains dominant, with the permanent highest market capitalization among all cryptocurrencies. The share of ethereum, second largest cryptocurrency, has never come close to endangering bitcoin dominance in the crypto market. The popularity of cryptocurrencies can be attributed to the fact that they enable pseudonymous transactions (to a certain extent), an efficient transfer of capital across borders while being a digital store of value. Market development has clearly demonstrated that cryptocurrencies are primarily used as high-risk investment assets, and only secondary as means of payment i.e. money. In fact, we have even seen an official ETF (exchange traded fund) in bitcoin, signalling the entrance of major institutional investors into the crypto market. Thus, they should be viewed as financial instruments at the present state of development. Examples such as

Salvador being the first country that introduced bitcoin as one of the official currencies are more exceptions than signs of a broader trend (Vuletić, 2024). Such rapid development naturally creates numerous regulatory challenges. A general regulatory response has ranged from ignorance to prohibitive legislative efforts, and finally to acceptance and adaptation into the regulatory frameworks for financial markets. The most ambitious regulatory endeavour for crypto markets so far has come from the European Union in the form of the Markets in Crypto-Assets Regulation. This Regulation will be the main subject of this paper.

2. THE EUROPEAN UNION'S REGULATORY RESPONSE TO THE DEVELOPMENT OF CRYPTO MARKETS

2.1. GENERAL BACKGROUND OF THE MARKETS IN CRYPTO-ASSETS REGULATION

The Markets in Crypto-Assets Regulation, officially titled Regulation (EU) 2023/1114 of the European Parliament and of the Council of 31 May 2023 on markets in crypto-assets, entered into legal force on 29 June 2023. Together with Regulation (EU) 2023/1113 on information accompanying transfers of funds and certain crypto-assets and Regulation (EU) 2022/858 on a pilot regime for market infrastructures based on distributed ledger technology (DLT Pilot Regime) it makes the European Union the first jurisdiction in the world to have a fully specialised regulatory framework on crypto-assets. This also marks a definite point in time in which we can conclude that cryptocurrencies, at least in the EU, are no longer mainly unregulated.

European Union regulators, the European Securities Markets Authority (ESMA) and the European Banking Authority (EBA), concluded in 2019 that the existing regulatory framework for financial markets could not be easily applied to crypto-assets (EBA, 2019). This was a matter of prior regulatory assessment. Alongside tax treatment of cryptocurrencies, like in the *Hedqvist* case of the European Court of Justice that deals with the applicability of value added tax, adjustability with the regulation of financial markets was practically the only area where EU regulatory efforts were made. Further motive for regulatory change did not come from the rapid economic success of bitcoin, but rather from the threat of the now defunct proposal for a centralised cryptocurrency launched by Facebook, affiliated company of Meta, titled “Libra”. The idea that one of the biggest corporations in the world, with substantial

technological power, would issue its own crypto currency triggered a warning signal to legislators around the globe. The combination of technical prowess, entrepreneurial ingenuity, capital strength and customer data could be seen not only as a challenge for incumbent banks or competition in general, but also for the political system (Maume, 2023). The legislative process was relatively fast, especially for EU Law standards, taking approximately three years. The European Commission published a draft of the Regulation in September 2020. The final agreement between the European Parliament, Commission and the Council with regard to the text was reached in June 2022. The Markets in Crypto Assets Regulation was enacted by the European Parliament in the spring of 2023.

The Markets in Crypto-Assets Regulation (MiCA) consists of nine titles, six annexes and 149 articles. The Regulation entered into legal force on 29 June 2023, while Titles III (asset-reference tokens) and IV (e-money tokens) have been applied since 30 June 2024, and the rest of the legislation since 30 December 2024.

2.2. SCOPE, DEFINITIONS AND SUBJECT MATTER

The Markets in Crypto-Assets Regulation is based on the notion of crypto-assets defined in Article 3 as the digital representation of a value or of a right that can be transferred and stored electronically using distributed ledger technology or similar technology. Distributed ledger technology or DLT is defined as technology that enables the operation and use of distributed ledgers. Distributed ledger is an information repository that keeps records of transactions and that is shared across, and synchronised between, a set of DLT network nodes using a consensus mechanism. A consensus mechanism constitutes the rules and procedures by which an agreement is reached, among DLT network nodes, that a transaction is validated. Crypto-asset service includes the following: providing custody and administration of crypto-assets on behalf of clients; operation of a trading platform for crypto-assets; exchange of crypto-assets for funds; exchange of crypto-assets for other crypto-assets; execution of orders for crypto-assets on behalf of clients; placing of crypto-assets; reception and transmission of orders for crypto-assets on behalf of clients; providing advice on crypto-assets; providing portfolio management on crypto-assets; providing transfer services for crypto-assets on behalf of clients. Obviously, the above-mentioned definitions depart from the proclaimed technologically neutral regulatory approach promoted by the European Commission.

The Markets in Crypto-Assets Regulation applies to natural and legal persons (and certain other undertakings) that are engaged in the issuance, offer to the public and admission to trading of crypto-assets, or that provide services related to crypto-assets in the EU. In particular, the Regulation lays down the following: transparency and disclosure requirements for the issuance, offer to the public and admission of crypto-assets to trading on a trading platform for crypto-assets (“admission to trading”); requirements for the authorisation and supervision of crypto-asset service providers, issuers of asset-referenced tokens and issuers of e-money tokens (as well as for their operation, organisation and governance); requirements for the protection of holders of crypto-assets in the issuance, offer to the public and admission to trading of crypto-assets; requirements for the protection of clients of crypto-asset service providers; measures to prevent insider dealing, unlawful disclosure of inside information and market manipulation related to crypto-assets. The broad scope of territorial application due to the global nature of markets in crypto-assets, implies if not global applicability, certainly global relevance. Competence issues with other jurisdictions may very well arise from such a wide conceptual scope.

Tokens that are financial instruments within the meaning MiFiD II (Directive 2014/65/EU of the European Parliament and of the Council of 15 May 2014 on markets in financial instruments) fall outside the scope of the Regulation. Furthermore, fully decentralised crypto-assets (better known under the acronym ‘DeFi’), i.e. crypto assets that are offered without any intermediaries, are excluded from the scope of the Regulation. The exclusion of fully decentralised crypto-assets is a consequence of the normative emphasis on the professional subjects offering crypto-services. The Regulation expressly excludes from its scope non-fungible tokens (NFT), thus further supporting the conclusion that it is not a comprehensive normative framework. The Regulation does not apply to the following: persons who provide crypto-asset services exclusively for their parent companies, liquidators, or during insolvency procedures (with certain exemptions), the European Central Bank (ECB), European Investment Bank, European Financial Stability Facility and the European Stability Mechanism, central banks of the Member States or other public authorities and public international organisations. Furthermore, the Regulation does not apply to crypto-assets that are unique and not fungible with other crypto-assets. Some authors (Maume, 2023) have already concluded that these exclusions preclude the conclusion of this new regulatory framework to be fully comprehensive.

2.3. TOKEN-CENTRIC REGULATORY APPROACH

This Regulation classifies crypto-assets into three types. The classification is based on whether the crypto-assets seek to stabilise their value by reference to other assets. The Markets in Crypto-Assets Regulation views all crypto assets that fall under its scope as tokens. Thus, we can speak of a token-centric regulatory approach. Tokens under the Regulation scope are divided into three categories:

- e-money tokens;
- asset-referenced tokens;
- other crypto-assets including utility tokens.

Titles II, III and IV of the Regulation stipulated specific rules on three categories of tokens/crypto-assets under its scope. An electronic money token or e-money token is defined as a type of crypto-asset that purports to maintain a stable value by referencing the value of one official currency. An asset-referenced token is defined as a type of crypto-asset that is not an electronic money token and that purports to maintain a stable value by referencing another value or right or a combination thereof, including one or more official currencies. E-money tokens and, to a certain extent, asset-referenced tokens from the Regulation would usually be called stablecoins in the crypto community. A utility token is defined (in Art. 3 of the Regulation) as a type of crypto-asset that is only intended to provide access to a good or a service supplied by its issuer. This definition is quite ambiguous. Within the meaning of the Regulation, actually all crypto assets that fall under its scope that are not asset-referenced or e-money tokens fall under the category of other crypto-assets.

Consequences of the token-centric EU regulatory approach reach beyond the normative constraints of the Regulation itself. The aforementioned regulatory approach dictates a broad conclusion that the standard manifestation form of crypto-assets is a token (Vuletić, 2025). The scope of the Regulation, as we have elaborated, does not encompass many crypto-assets, including financial instruments and fully decentralized crypto-assets. This approach is not necessarily optimal for comprehensive regulation of the crypto-sphere, since there are crypto-assets, albeit rare, that do not manifest as tokens or coins.

2.4. EMPIRICAL CONTEXT, DECENTRALISED FINANCE AND NFTS

Long term empirical data on the application of the Regulation will only emerge in the post-2025 period. Thus, it is too early to elaborate on empirical

data. However, there are some early indicators that tend to demonstrate high probability for positive effects in the field of consumer protection. A good example are the requirements set in the Regulation in terms of whitepaper disclosures for public offerings of crypto-assets (similar to the regulatory requirements on markets in financial instruments). These requirements stipulated in the Regulation will certainly decrease the instances of unclear project information and deceptive promotional practices. The described positive effects correlate to fraud prevention as well. However, effects in other areas such as market stability, cannot be pre-assessed at present.

While the Regulation explicitly excludes fully decentralized finance (DeFi) protocols and non-fungible tokens (NFTs) from its scope, their rapid growth and integration into the broader crypto-asset ecosystem necessitate further analysis – both from a regulatory and risk management perspective. DeFi platforms replicate traditional financial services (e.g., lending, trading, derivatives) using smart contracts on public blockchains. Their key feature is the absence of intermediaries – this makes them inherently unsuitable for the regulatory approach adopted by the EU. Risks associated with decentralised finances include smart contract vulnerabilities, lack of accountability and wide possibility for regulatory arbitrage.

Non-fungible tokens are rapidly expanding into sectors such as gaming, intellectual property, and tokenized real-world assets (RWA). Regulatory considerations that seek to be addressed in the area of NFTs are fraud prevention, securities like behaviour, and obviously, consumer protection gaps. Thus, exclusion of decentralised finance and non-fungible tokens from the scope creates a regulatory blind spot.

3. COMPARATIVE REGULATORY FRAMEWORKS

3.1. COMPARISON TO OTHER REGULATORY FRAMEWORKS IN THE EUROPEAN UNION LAW

The Markets in Crypto-Assets Regulation is substantially influenced by other regulatory fields within the EU Law. This cannot come as a surprise since there have been no other real comparative models in the regulation of crypto-assets. Normative influence especially derives from the regulatory framework on markets in financial instruments and consumer protection rules. The existing consumer protection rules are applicable for consumers of crypto-assets. For example, the Directive on distance marketing (Directive 2002/65/EC of

the European Parliament and of the Council of 23 September 2002 concerning the distance marketing of consumer financial services) is applicable. The need for specialised rules on consumer protection in markets in crypto-assets is quite understandable in light of the rapid technological development of cryptocurrencies, especially since specialised consumer protection rules can standardly be found in various fields. However, this need is not clearly manifested when it comes to financial markets.

The general regulatory approach of the Markets in Crypto-Assets Regulation broadly follows the approach of the regulatory frameworks for markets in financial instruments. This is especially visible in Title V of the Regulation which stipulates rules for the authorisation and operating conditions of crypto-asset service providers. This entire regime of rules for authorisation and operating conditions is clearly a modification of the regime laid out in the Directive for Markets in Financial Instruments, known under the acronym MiFID II (Directive 2014/65/EU of the European Parliament and of the Council of 15 May 2014 on markets in financial instruments). The Influence of Market Abuse Regulation, known under the acronym MAR (Regulation 596/2014 of the European Parliament and of the Council of 16 April 2014 on market abuse), is visible in Title VI of the Regulation, which stipulates the rules on preventing and prohibiting market abuse involving crypto-assets, to the point of verbatim identical provisions. These converging regulatory approaches bring forward the question of the need for a separate regulatory framework on crypto-assets. The recital of the Regulation (in par. 14) declares that for the purposes of ensuring a clear delineation with financial instruments, ESMA should be mandated to issue guidelines on the criteria and conditions for the qualification of crypto-assets as financial instruments. This is especially needed since there are crypto-assets that are financial instruments and thus fall outside the scope of the Markets in Crypto-Assets Regulation. Would not an adaptation of the existing regulatory framework be the optimal regulatory approach? Why is a separate specialised regime for crypto-assets needed if the same rules are mainly borrowed from other regulatory frameworks?

3.2. COMPARISON TO OTHER JURISDICTIONS

Although the Markets in Crypto-Assets Regulation has not achieved a fully comprehensive regulatory framework for all crypto-assets (leaving financial instruments, NFT and complete decentralised crypto-assets outside the scope), there is no comparable legislation anywhere in the world. Other jurisdictions

mainly implement rules on financial instruments and consumer protection to crypto-assets without specialised comprehensive legislation. In several jurisdictions, legislative proposals and initiatives regulating crypto-assets are pending, but at the time of writing this paper there is no such extensive regulatory framework in the making.

After the EU, the United Kingdom has made the most progress in the regulatory efforts in terms of crypto-assets. The UK Money Laundering, Terrorist Financing and Transfer of Funds Regulation 2017, which became applicable to crypto-asset businesses in January 2020, provides a risk-based approach for applying customer due diligence, monitoring and reporting suspicious activities. The UK Financial Services and Markets Act (FSMA) was adopted in June 2023 and envisages the establishment of a financial market infrastructure (FMI) sandbox. The UK approach to testing the application of DLT technologies is channelled through the UK Financial Market Infrastructures sandbox, allowing participating firms to test their technologies and products by letting regulators temporarily suspend or amend laws, if not applying new ones (Hallak & Salén, 2023).

Singapore has proposed regulatory measures to reduce the risk of consumer harm from cryptocurrency trading. These include consumer access-related measures where services are offered to retail investors. Under the Payment Services Act from 2019, the Monetary Authority of Singapore (MAS) licenses the Digital Payment Token (DPT) services. Hong Kong's regime for virtual-asset activities, in place since 2018, among other investor protection measures, requires the implementation of a virtual-asset knowledge assessment (WEF, 2023). Japan's Financial Services Agency (JFSA) gave the country's cryptocurrency industry a self-regulatory status, granting the Japan Virtual Currency Exchange Association (JVCEA) the power to penalize Japanese cryptocurrency exchanges, with oversight from the JFSA. Japan introduced such stringent custodial rules following some major exchange frauds (notably Mt. Gox and Coincheck).

The People's Republic of China, once a bitcoin trading and mining hub, is an interesting example. China introduced a complete ban on crypto-currencies with an emphasis on crypto exchanges in 2021. While restrictive, China has simultaneously accelerated the development of its central bank digital currency, the digital yuan. The Chinese case reveals a national preference for state-controlled digital finance ecosystems. A restrictive approach has also been implemented in Nigeria, by introducing bans on banks in regards to servicing crypto exchange.

On the other side of the regulatory scale is Salvador with the introduction of bitcoin as an official currency in the same year. To this day, Salvador

remains the sole example of such action, that is yet to produce any substantial positive effect on the national economy. However, international institutions such as the IMF have warned of macroeconomic instability, volatility and risks to fiscal health. While symbolic, Salvador’s case is an outlier and has yet to show measurable economic gains.

Table 1: Overview of crypto-asset regulations in place in the EU, the UK, and the US

	European Union	United Kingdom	United States
Crypto-securities	Yes, MiFID and MiFIR	Yes	Yes, Securities Act, schemes qualifying under the Howey test
Other crypto-assets	Yes, MiCA 2023	Yes, FSMA 2023	No
Regulation on stablecoin	Yes, the MiCA established the regulatory framework. More details to be ruled by EBA.	Yes, FSMA provides that the regulator will establish the whole framework.	No

Source: Hallak & Salén, 2023

The regulatory approach in the United States stands in contrast to the EU’s ambitious legislative endeavour. On the federal level, the United States lack specialised regulation for crypto-assets and apply the existing regulatory framework in all fields. The Presidential Executive Order 14067 of 9 March 2022, titled “Ensuring Responsible Development of Digital Assets”, that can be described as an attempt to initiate federal legislative efforts, has been re-voked. However, it has been replaced by the new US administration with the Executive Order of 23 January 2025, titled “Strengthening American Leadership in Digital Financial Technology”. The new executive order establishes the President’s Working Group on Digital Asset Markets. Thus, a substantial reform of the US regulatory framework is to be expected in the near future. One of the possible pathways to reform that is currently discussed will be in the sphere of monetary policy, with the possibility that the United States holds reserves in bitcoin, which was confirmed for the first quarter of 2025.

The main regulatory impetus in the US is at present coming from the sector market regulators, primarily from the Securities and Exchange Commission (SEC), and then from the Commodity Futures Trading Commission

(CFTC). One of the major regulatory issues is whether a certain crypto-asset falls under the scope of the Securities Act, like in the pending case of cryptocurrency XRP/Ripple. An essential component of SEC jurisdiction has been the “Howey test”, developed from the 1946 Supreme Court decision which declares a scheme to be an “investment contract” under the Securities Act if it involves (a) an investment of money (b) in a common enterprise (c) with profits (d) to come solely from the efforts of others. If the Howey test requirements are met, it is immaterial whether the enterprise is speculative or non-speculative, or whether there is a sale of property with or without intrinsic value. Several US states, like New York and Wisconsin (Hallak & Salén, 2023), have enacted fragmented state-level legislation, in lack of a federal regulatory framework.

4. CONCLUSIONS AND POLICY RECOMMENDATIONS FOR GLOBAL REGULATORY CONVERGENCE

The recital of the Preamble of the Markets in Crypto-Assets Regulation in paragraph 5 states that the lack of an overall Union framework for markets in crypto-assets could lead to regulatory fragmentation, which would distort competition in the internal market, make it more difficult for crypto-asset service providers to scale up their activities on a cross-border basis, and would give rise to regulatory arbitrage. This reasoning contained in the Preamble of the Regulation could very well be applied on a global scale and not only to the EU internal market. Then we could conclude that regulatory fragmentation derives from the EU legal order itself. The problem lies in the global nature of markets in crypto-assets. Trade in crypto-assets is global and very rare, if never, and exclusively limited to a particular geographical market. Thus, such extensive regulation of crypto-assets on the level of the EU without any harmonisation or convergence with other jurisdictions can be considered suboptimal. Remarkable speed of the enactment of the Regulation in the 3-year period suggests that this new regulatory framework is a case of normative optimism. Undoubtedly, the general unregulated nature of the sector was not viable in the long run, and a certain level of protection of crypto-assets users, especially of consumers, is necessary.

However, the Markets in Crypto-Assets Regulation has gone much further than ensuring the protection of users and consumers by introducing a full regulatory framework. Yet, it falls short of the ambition for a comprehensive regulatory framework of crypto-assets. Among several major categories of crypto-assets that are outside of its scope, maybe the most striking is the

example of crypto-assets categorised as financial instruments. They fall under the regime of MiFID II. This brings into question the need for the existence of a specialised and extensive regulatory framework. The argument is further exaggerated by the fact that the regulatory approach of the Markets in Crypto-Assets Regulation follows MIFID II and MAR, sometimes even to the extent of verbatim transplantation. This “regulating by analogy” may impose ill-fitting requirements on fundamentally different systems. The exclusion of decentralised finance and NFTs from the scope of the Regulation supports such a conclusion.

A solution could arise from the global regulatory approach that could entail at least minimal specific harmonisation. This approach could produce a more effective regulatory framework. Such a regulatory solution is also generally suggested in the white paper of the World Economic Forum from 2023. The question that arises is how to best regulate something that is borderless, open-source, decentralized and constantly evolving. The borderless nature of the technology, the interconnectedness within the crypto-asset ecosystem and the prospect of linkages with the traditional financial ecosystem strengthen the case for a global approach to crypto-asset regulation (WEF, 2023). A high level of regulatory convergence can be achieved through international organisations, including the convention system of the United Nations or World Trade Organization (WTO). There are several examples where high levels of global regulatory convergence have been achieved. The international regulatory framework for intellectual property (IP) including the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) is one example. Alternatively, the WTO could initiate discussions on crypto-assets under the umbrella of digital trade, fostering binding commitments in future trade agreements. The conventions adopted within the International Maritime Organization (IMO), a specialised agency of the UN responsible for regulating maritime transport, would be another example of such successful global regulatory convergence.

Generally, this paper can propose several broad pathways for global regulatory convergence that are not mutually exclusive, as follows:

- international norm-building through soft law (e.g., leverage the existing institutions to issue globally endorsed principles on crypto-assets classification, risk management, and supervision);
- a UN or WTO-led Convention System to formalize minimal regulatory requirements across jurisdictions as previously explained;
- establishment of a Global Crypto Oversight Council modelled after the Basel Committee or the G20 Financial Stability Board.

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**GREEN ECONOMY
AND BUSINESS INOVATION**

THE CONNECTION BETWEEN COMPANY SIZE AND INNOVATION CULTURE IN CROATIAN MANUFACTURING INDUSTRY

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This paper investigates the connection between company size and innovation culture within the Croatian manufacturing sector. The main objective of the paper is to explore whether a firm's size significantly impacts its capacity to foster different dimensions of innovation culture. Conducted in 2024 among Croatian manufacturing companies, the research categorizes firms into four size groups: micro, small, medium, and large, allowing for a nuanced analysis of how organizational size influences innovation-enabling practices. The company size is hypothesized to play a critical role in shaping innovation culture due to the inherent differences in resource availability, flexibility, and structural dynamics across these categories. Larger firms, for example, generally have more extensive resources and established market positions, which can support more complex and sustained innovation efforts. However, they may also face bureaucratic inertia that limits agility and responsiveness, presenting obstacles to innovation. Conversely, micro and small companies, with flatter hierarchies and greater adaptability, can swiftly respond to changes in the market, but may be restricted by limited financial and technical resources. The study's primary objective is to better understand whether company size has a significant effect on innovation culture, particularly within the Croatian manufacturing landscape, by examining the differences across four core dimensions of innovation culture, namely: autonomy, readiness for product cannibalization, proactiveness, and risk taking. This paper

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seeks to provide actionable insights into how firms of varying sizes can best cultivate an innovative organizational culture with its main values. Findings from this study suggest that the company size does matter when it comes to stimulating certain innovation culture values. This effect is most pronounced in case of proactiveness where large companies still possess certain advantages compared to the smaller ones. For Croatian manufacturers striving to remain competitive in the European and global markets, understanding these dynamics is crucial for fostering a sustainable culture of innovation that can successfully scale from small to large companies without stifling innovation as a core competitiveness competence.

Keywords: *Croatian manufacturing industry, innovation culture, disruptive innovation*

JEL classification: *010, 014*

INTRODUCTION

Innovation serves as a cornerstone of prosperity in the manufacturing sector, enabling firms to thrive in competitive, fast-changing markets. By fostering innovation, manufacturers unlock the pathways to sustainable growth, improve operational efficiency, and enhance adaptability. Continuous innovation, particularly when integrated with robust strategies, enhances both financial and operational performance, providing a foundation for long-term competitiveness (Latan et al., 2020).

Technological innovation is a vital component of growth in the manufacturing industry. Research from hi-tech start-ups reveals that innovation not only reduces market exit risks, but also yields substantial financial rewards (Zhang, Zhuge & Freeman, 2020). Green and process innovations, meanwhile, improve productivity while addressing environmental concerns, thus underscoring the role of innovation in achieving sustainability. For example, green process innovations supported by digital leadership help align economic objectives with environmental goals, ensuring sustainable success. Similarly, combining product and process innovations with international linkages has been shown to significantly enhance growth performance in emerging economies (Goedhuys & Veugelers, 2012). Collaboration amplifies the benefits of innovation. Partnerships between suppliers and manufacturers, especially those that foster co-innovation, drive superior product outcomes and profitability

(Shen et al., 2021). Open innovation frameworks, which emphasize knowledge sharing across organizational boundaries, enrich these efforts further by integrating diverse expertise and accelerating the deployment of breakthrough innovations (Obradović, Vlačić & Dabić, 2021). These collaborative ecosystems enable manufacturers to remain at the forefront of their industries.

As suggested in previous research, innovation culture plays a key role for producing product and process innovations (Jassawalla & Sashittal, 2002; Steele & Murray, 2004; Hilmarsson, Oskarsson & Gudlaugsson, 2014; Jaw, Chen & Chen, 2012). The role of key innovation values such as autonomy, proactiveness, risk taking and cannibalization in the context of Croatian manufacturing industry was researched in this article. The analysis focused on the role of company size in stimulating these values.

INNOVATION CULTURE AND KEY ORGANIZATIONAL VALUES

Organizational culture refers to the shared beliefs, norms, and practices that shape how individuals within a company interact and work toward shared goals. It provides the foundation for organizational behaviours and decision-making, creating an environment that can either support or stifle innovation (Büschgens, Bausch & Balkin, 2013). Central to organizational culture are values – deeply held principles that guide priorities and actions, ensuring alignment with the organization’s mission and goals (Khazanchi, Lewis & Boyer, 2007). In order to foster a culture that enables disruptive innovation, organizations must embed specific values that drive adaptability, creativity, and resilience. These values not only enhance an organization’s capacity to innovate, but also ensure its sustainability in a competitive and evolving market landscape. The values that are associated with innovation are shortly discussed in the following text.

ADAPTABILITY AND FLEXIBILITY

Flexibility and adaptability are essential in environments that demand swift responses to change. Organizations that prioritize these values foster a culture conducive to experimentation and innovation. The Competing Values Framework identifies adhocratic cultures as ideal for disruptive innovation, emphasizing flexibility and external orientation to encourage creative prob-

lem-solving and agility in uncertain conditions (Büschgens, Bausch & Balkin, 2013). Recent studies highlight that adaptability also allows organizations to capitalize on emerging technologies, particularly in industries undergoing digital transformation (Roblek et al., 2021).

EMPOWERMENT AND COLLABORATION

Empowerment unlocks the potential of employees by granting them autonomy to experiment and innovate. Empowered individuals take ownership of their contributions, enhancing engagement and productivity. Collaboration amplifies this effect, creating networks of shared knowledge and diverse perspectives that spark novel ideas. Modern frameworks like design thinking stress the importance of cross-functional collaboration as a driver of innovation (Brown, 2009). Empowerment, paired with collaboration, builds a resilient workforce capable of tackling complex challenges effectively (Khazanchi, Lewis & Boyer, 2007).

ENCOURAGING RISK-TAKING

Disruptive innovation inherently involves risk, making a tolerance for failure a key cultural attribute. Organizations must redefine failure as an opportunity for growth and learning, creating a safe space for experimentation. Leaders play a crucial role in setting this tone by modelling resilience, celebrating risk-taking, and framing setbacks as necessary steps in the innovation journey. Research further suggests that risk-tolerant cultures outperform risk-averse counterparts in markets characterized by volatility and rapid technological shifts (Jaskyte, 2004; Zhang & Wang, 2021).

OPEN COMMUNICATION

Transparent and open communication is fundamental to breaking down silos and fostering a collaborative environment. Organizations must establish mechanisms for idea-sharing across levels and functions, promoting cross-pollination of knowledge. Effective communication also aligns efforts toward shared goals, maximizing the synergy between teams. Studies have shown that open communication not only boosts innovation, but also enhances orga-

nizational resilience by fostering trust and alignment (Belasen & Rufer, 2013; Edmondson, 2019).

CUSTOMER-CENTRIC APPROACH

Aligning innovation efforts with customer needs is central to the success of disruptive innovation. This requires organizations to deeply understand their customers, particularly in underserved or emerging market segments. By integrating customer insights into the innovation process, firms can develop solutions that meet unique demands, often creating entirely new markets. Research underscores that customer-centric organizations are better positioned to pivot and remain relevant in dynamic markets (Kumar & Reinartz, 2016).

ENTREPRENEURIAL LEADERSHIP

Entrepreneurial leaders drive innovation by inspiring teams with a vision, managing resources strategically, and fostering a risk-taking culture. These leaders encourage calculated risks while ensuring alignment with organizational goals. Entrepreneurial leadership not only supports the values of empowerment and adaptability, but also ensures that innovation initiatives are well-resourced and effectively implemented (Utoyo, Hadi & Sunarsi 2020). Their ability to navigate uncertainty is particularly critical in fostering an environment where disruptive innovation can thrive.

COMMITMENT TO LEARNING

A learning-oriented culture equips organizations to adapt to change by continually acquiring and applying new knowledge. Such cultures are essential for building dynamic capabilities, which enable firms to respond to technological disruptions and seize opportunities. Learning organizations prioritize experimentation and feedback loops, ensuring they remain at the forefront of innovation (Škerlavaj et al., 2007). For example, firms that invest in ongoing employee development report higher innovation rates and adaptability in competitive markets (Sarfraz et al., 2022).

THE ROLE OF COMPANY SIZE WHEN IT COMES TO INNOVATIONS

Enterprises of different sizes approach innovation uniquely, leveraging their specific strengths and navigating inherent challenges. Micro, small, medium, and large enterprises each bring distinctive capabilities to the innovation landscape, shaped by their scale, resource availability, and organizational dynamics. Understanding how these businesses foster innovation culture and overcome constraints provides valuable insights into their innovation strategies and competitive positioning. This analysis explores the innovation profiles of micro, small, medium, and large enterprises, highlighting their approaches, challenges, and opportunities in driving growth and adaptation.

MICRO ENTERPRISES

Micro enterprises excel in agility and the ability to respond quickly to niche market demands. Their small size allows for rapid decision-making and experimentation, making them well-suited for incremental innovations. However, they often lack resources for significant R&D investment, limiting their ability to undertake large-scale innovation projects. Studies show that micro enterprises focus on leveraging the skills of their owners and employees to implement creative, yet small-scale solutions to immediate challenges. Moreover, their resource limitations demand innovation management strategies tailored to maximize internal capacities while exploring external linkages (Mazzola et al., 2018).

SMALL ENTERPRISES

Small enterprises retain much of the agility of micro enterprises, but with slightly more resources. Their customer focus drives innovation aimed at solving specific market problems, often leveraging collaboration and partnerships to overcome resource constraints (Rothwell & Dodgson, 1991). Despite their flexibility, they frequently struggle with establishing external linkages, such as partnerships for knowledge exchange or R&D collaborations. However, when they do integrate these elements effectively, their innovation capacity significantly improves, especially in niche markets (Spithoven, Vanhaverbeke & Roijakkers, 2011).

MEDIUM ENTERPRISES

Medium-sized companies balance the agility of smaller firms with the resource availability of larger organizations. They are better equipped to support incremental innovations while also pursuing strategic or process-driven changes that position them competitively. However, they often face challenges in competing with larger firms for market share and resources, and they must strategically allocate their capabilities to succeed. Medium enterprises thrive when they align their innovation strategies with market orientation, fostering customer-focused product development (Laforet, 2009). Nevertheless, resource limitations relative to large enterprises mean they must prioritize efficient and targeted innovation efforts.

LARGE ENTERPRISES

Large enterprises benefit from significant financial and human resources, enabling them to pursue radical innovations and transformative projects. Their extensive R&D departments and access to advanced technologies allow for high-risk, high-reward innovation initiatives. However, large enterprises often face bureaucratic inertia, making them less responsive to emerging trends. To mitigate this, many adopt open innovation practices, collaborating with smaller firms and external partners to integrate fresh perspectives and ideas (Spithoven, Vanhaverbeke & Roijakkers, 2011). Their success in maintaining innovation largely depends on their ability to balance structured processes with flexibility (Jeng & Pak, 2016).

THE INNOVATION PARADOX IN LARGE INCUMBENTS

Large incumbent firms often face an innovation paradox, wherein their success, scale, and established processes – key advantages in stable markets – become barriers to innovation in dynamic environments. This paradox stems from the tension between exploiting existing capabilities and exploring new opportunities. While their size and resources position them to lead innovation, structural and cultural challenges frequently inhibit their ability to adapt and compete with smaller, more agile players.

Large firms are characterized by well-defined hierarchies and bureaucratic processes that prioritize efficiency and risk management. These structures,

while advantageous for operational consistency, create inertia that hampers the ability to respond quickly to market changes. Research indicates that rigid organizational processes delay decision-making and make large firms less responsive to disruptive innovations (Jeng & Pak, 2016). The dependence on existing revenue streams and shareholder expectations for predictable returns makes large firms inherently risk-averse. They often focus on incremental improvements to existing products, which are safer and easier to justify than high-risk, transformative innovations. This focus, while profitable in the short term, can lead to stagnation as newer, disruptive competitors capture emerging markets (Spithoven, Vanhaverbeke & Roijakkers, 2011).

Large incumbents must balance the exploitation of existing capabilities with the exploration of new opportunities. This balance is challenging because resources allocated to exploitation often dominate due to their immediate profitability, leaving exploration underfunded and under-prioritized. The result is a lack of focus on long-term innovations that could ensure future relevance (March, 1991).

Large firms often fail to recognize the potential of disruptive innovations because these innovations initially target niche or low-end markets that incumbents deem unprofitable. By the time disruptive innovations gain traction, it is often too late for incumbents to pivot and compete effectively. This phenomenon, described by Christensen (1997) in “The Innovator’s Dilemma”, highlights how large firms’ focus on serving existing customer needs blinds them to emerging opportunities. A risk-averse culture often dominates large firms, where employees are incentivized to maintain the status quo rather than challenge the existing norms. This stifles creativity and discourages experimentation. Furthermore, organizational silos can impede the cross-functional collaboration necessary for disruptive innovations (Belasen & Rufer, 2013). Large firms face intense pressure to deliver quarterly financial results, often leading to the prioritization of short-term gains over long-term innovation investments. This focus on immediate profitability discourages experimentation and fosters incremental rather than radical innovation (Jeng & Pak, 2016).

DATA AND METHODS

Primary research was conducted among companies from the Croatian manufacturing industry. The sample size was 132 companies. The sample was further divided into four groups according to size: micro (n=32), small (n=35), medium (n=33) and large (n=32). By examining the differences across four

core dimensions of innovation culture, namely: autonomy, readiness for product cannibalization, proactiveness, and risk taking, the study seeks to provide actionable insights into how firms of varying sizes can best cultivate an innovative organizational culture. A highly structured online questionnaire was used as the research instrument.

Descriptive statistics, factor analysis, correlation analysis and ANOVA analysis were used in the data analysis. The degree of agreement with the statements regarding individual factors of innovation culture was measured on a Likert scale ranging from 1 to 7, and the statements were then categorized into a smaller number of dimensions using factor analysis in order to identify the main groups of factors that determine innovation culture in the company. The principal components technique was used as the factor extraction method. The number of factors (components) was defined based on Kaiser's criterion, according to which only factors with eigenvalues greater than 1 were retained in the analysis. An inspection of the correlation matrix between individual statements revealed the presence of a large number of coefficients greater than 0.3, which points to the need for applying the rotation method which assumes the connection of factors. Factor rotation was performed using the Oblimin method with Kaiser normalization, assuming that the factors are mutually correlated, which is common in social research. After the main groups of innovation culture factors were identified, a one-way between groups ANOVA test was used to determine whether there was a statistically significant difference in the mean ratings of individual innovation culture factors between companies with regard to their size.

RESULTS

The Kaiser-Meyer-Olkin sampling adequacy test ($KMO = 0.830$) and Bartlett's test of sphericity ($\chi^2(X) = 1001.798$, $df = 91$, $p = 0.000$) confirmed that the data were suitable for factor analysis. If the sample is adequate, the results of the factor analysis will be reliable and relevant to the population (Tabachnick & Fidell, 2007).

The scale of innovation culture consisted of a total of 14 statements that were categorized into four components (factors) according to principal component analysis, explaining respectively 38.53%, 15.45%, 8.87% and 7.31% of the variance. Cumulatively, the factors explain 71.16% of the variance. The scree plot shows a clear break in the curve after the fourth factor (Figure 1). The loadings on individual factors are shown in Table 1. The rotation of the fac-

tors showed a clear interpretation of the factors. The factors were interpreted as (1) proactiveness, (2) risk taking, (3) autonomy, and (4) willingness to cannibalize. Highlighted factor loadings indicate the dominant loadings for each component.

Figure 1: Scree plot

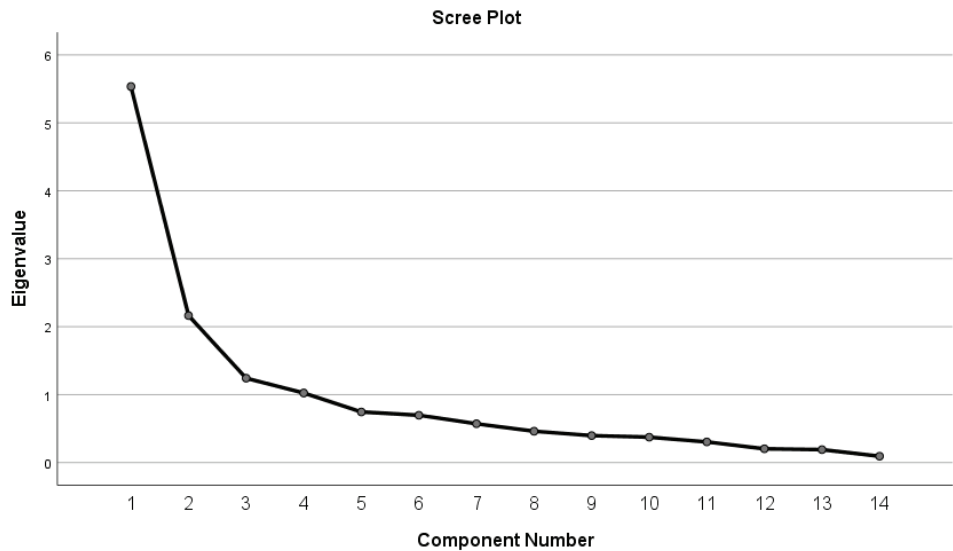


Table 1: Factor analysis

Pattern Matrix	Component			
	1	2	3	4
P_Our company is continuously looking for new opportunities in accordance with the constantly changing market conditions.	.940	.008	.023	-.015
P_Our company is trying to position itself to meet the emerging market needs.	.924	-.043	-.041	-.078
P_Our company undertakes activities based on forecasting future market conditions.	.856	.026	.048	-.077
R_Our business operations are high risk.	.136	.796	.170	.204
R_As a rule, our operations do not follow a “tried-and-true” pattern.	.055	.743	-.185	-.168
R_In our company, there is a tendency to approve projects whose expected return is not always certain.	-.329	.721	.029	-.201

Pattern Matrix	Component			
	1	2	3	4
A_All employees are trying to find new business opportunities.	-.076	.020	.882	.005
A_All employees are encouraged to develop ideas for new products.	.040	-.002	.822	-.045
A_Employees are allowed independent activities aimed at developing new products.	.036	-.034	.794	-.116
A_Decision makers test employees' new ideas.	.480	.064	.491	-.018
C_We are ready to sacrifice the sale of the existing product in order to increase the sale of our new product.	-.036	-.057	.062	-.843
C_We are not opposed to new projects that could threaten the sale of existing products.	.105	.137	-.032	-.796
C_We are interested in new technologies, the implementation of which would lead to a decrease in the value of current investments.	.027	-.033	.050	-.650
C_Our company is not conservative when making big decisions.	.244	.149	.151	-.481
Extraction Method: Principal Component Analysis Rotation Method: Oblimin with Kaiser Normalization a. Rotation converged in 7 iterations				

The factors show a weak to medium strong and positive correlation with each other, with the exception of the fourth factor, which shows a negative correlation (Table 2).

Table 2: Component correlation matrix

Component	1 (Proactiveness)	2 (Risk taking)	3 (Autonomy)	4 (Cannibalisation)
1	1.000	.058	.465	-.307
2	.058	1.000	.165	-.321
3	.465	.165	1.000	-.331
4	-.307	-.321	-.331	1.000

The mean values of the factors were used in the ANOVA analysis in order to examine the influence of the size of the company on the innovation culture, observed by the isolated values of innovation culture. Table 3 shows the descriptive statistics of the values of innovation culture for each category of company size.

Table 3: Descriptive statistic of innovation culture values, by company size

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Proactiveness	large	32	6.2083	.7655	.1353	5.9323	6.4843	4.00	7.00
	medium	33	5.4444	1.2683	.2207	4.9946	5.8941	1.00	7.00
	small	35	5.7047	1.1483	.1941	5.3102	6.0992	2.67	7.00
	micro	32	5.1979	1.3726	.2426	4.7030	5.6928	2.00	7.00
	Total	132	5.6388	1.2071	.1050	5.4310	5.8467	1.00	7.00
Risk taking	large	32	3.4583	1.0867	.1921	3.0665	3.8501	1.00	6.33
	medium	33	3.6060	1.0847	.1888	3.2214	3.9907	1.00	5.66
	small	35	3.7238	1.3197	.2230	3.2704	4.17719	1.00	7.00
	micro	32	3.9895	.7307	.1291	3.7261	4.2530	3.00	5.33
	Total	132	3.6944	1.08738	.0946	3.5072	3.88161	1.00	7.00
Autonomy	large	32	4.2031	1.2320	.2177	3.7589	4.6473	1.25	6.50
	medium	33	4.7576	1.1065	.1926	4.3652	5.1500	1.00	7.00
	small	35	4.8357	1.3678	.2312	4.3658	5.3056	2.00	7.00
	micro	32	4.4141	1.4050	.2483	3.9075	4.9206	1.25	7.00
	Total	132	4.5606	1.2952	.1127	4.3376	4.7836	1.00	7.00
Cannibalisation	large	32	4.3203	1.1796	.2085	3.8949	4.7457	1.75	6.75
	medium	33	4.5152	1.2310	.2142	4.0787	4.9516	1.00	6.50
	small	35	4.9214	1.2555	.2122	4.4901	5.3527	2.25	7.00
	micro	32	4.4297	1.0302	.1821	4.0582	4.8011	2.25	6.75
	Total	132	4.5549	1.1888	.1034	4.3502	4.7596	1.00	7.00

Figure 2 shows the difference in mean assessments between factors for each company size.

Levene's test of homogeneity of variances confirms that the assumption of homogeneity of variances in groups of different company sizes is not violated, therefore the analysis of variance continued. The results of the ANOVA analysis (Table 4) show that the size of the company appears as a discriminating factor only in the case of proactiveness as a value of innovation culture in the company: $F(3.128)=4.442$, $p=0.005$. The remaining values of the innovation culture in the company are not conditioned by the size of the company.

Figure 2: Mean assessments of innovation culture values, by company size

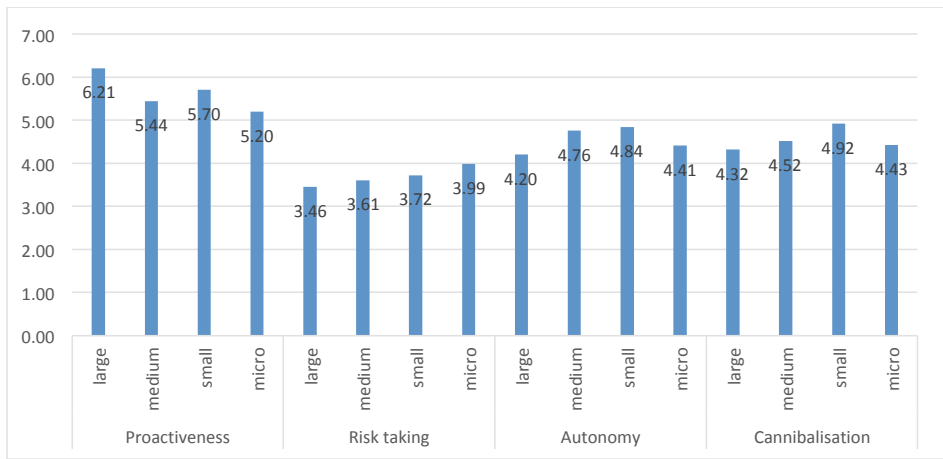


Table 4: ANOVA analysis

		Sum of Squares	df	Mean Square	F	Sig.
Proactiveness	Between Groups	17.999	3	6.000	4.442	.005
	Within Groups	172.899	128	1.351		
	Total	190.898	131			
Risk taking	Between Groups	4.859	3	1.620	1.382	.251
	Within Groups	150.039	128	1.172		
	Total	154.898	131			
Autonomy	Between Groups	8.706	3	2.902	1.760	.158
	Within Groups	211.059	128	1.649		
	Total	219.765	131			
Cannibalisation	Between Groups	7.017	3	2.339	1.681	.174
	Within Groups	178.147	128	1.392		
	Total	185.164	131			

CONCLUSIONS

Innovation culture is consistently identified as a key enabler of product and process innovation across diverse industries, with studies emphasizing its role in fostering autonomy, risk taking, proactiveness and cannibalization. Creating and sustaining such a culture significantly enhances innovative outcomes.

There are several important conclusions to be drawn from the data analysed. First of all, it is obvious that only proactiveness is significantly influenced by company size and larger companies score higher in this variable than the rest of the sample. This means that larger companies pay attention when it comes to new markets, new customers and new technologies. Of course, this is easier for them primarily because they have both financial and human resources to actually pursue these activities. The second conclusion made obvious by the research is that Croatian manufacturers score lowest on the variable of risk taking, which is most often emphasized by the literature as a key value when it comes to disruptive innovation. The third conclusion is that when it comes to autonomy and cannibalization, small and medium companies score better than micro and large companies. In this case we can conclude that small and medium companies are able to balance these values in a better way than their more extreme (from size point of view) counterparts.

There are, of course, many limitations to the results and conclusions presented in this paper. First of all, the sample size needs to be bigger if we want to provide more generalizable results. Second, there were no industry specifics taken into account when analysing the results, and third, there are many more innovation values that could be associated with innovation culture and included into the research. When it comes to advancing this research, an interesting stream would be to investigate the key factors that contribute to the successful scaling of innovation culture from smaller to large companies. It would also be interesting to carry out similar research in the service industry and then compare the results.

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THE IMPACT OF MOBILE BANKING SERVICE QUALITY ON THE SATISFACTION OF GENERATION Z USERS / UTJECAJ KVALITETE USLUGE MOBILNOGA BANKARSTVA NA ZADOVOLJSTVO KORISNIKA PRIPADNIKA GENERACIJE Z

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Mobile banking services, due to their advantages, are increasingly utilized by various user groups, especially by members of Generation Z. Generation Z poses a significant marketing challenge for commercial banks due to the extent to which they use mobile services and the high expectations they have from mobile banking services, which remain relatively under-researched. Despite this, due to characteristics such as a reliance on technology during service delivery, mobile banking services may elicit a high level of perceived usage risk among users. For these reasons, commercial banks must increasingly invest in the quality of mobile banking services to create customer satisfaction, meet user expectations, and thus ensure long-term customer relationships. To determine the impact of perceived mobile banking service quality, a survey was conducted on a selected sample of Generation Z members. Perceived quality of mobile banking service was conceptualized using an adapted version of the E-S-Qual model by Parasuraman, Zeithaml, and Malhotra (2005). The collected data were analyzed using the PLS-SEM method and by creating an importance-performance matrix. The study found a positive and significant impact of dimensions such as design and visual appeal, reliability, efficiency, and a somewhat weaker influence of information quality on the satisfaction of Generation Z users. Analysis of the importance-performance matrix provided additional insights into the significance of in-

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dividual dimensions and attributes of mobile banking service quality. According to the results of the importance-performance analysis, the design dimension of mobile banking service quality was important for achieving satisfaction, though it exhibited a lower level of performance. This dimension represents a priority for improving mobile banking service quality, which will most significantly contribute to the satisfaction of Generation Z users. Although the study results indicated that the security dimension of mobile banking service quality was not essential for Generation Z in forming satisfaction, the importance-performance analysis at the indicator level showed that security of the mobile banking application was indeed important to Generation Z users.

Keywords: *Mobile banking service quality, user satisfaction, analysis of importance and performance, Generation Z*

JEL classification: *M31*

Uslugama mobilnoga bankarstva, zbog svojih prednosti, koriste se u sve većoj mjeri različite grupe korisnika, posebice pripadnici generacije Z. Generacija Z predstavlja velik izazov za marketing poslovnih banaka zbog opsega u kojem se koriste mobilnim uslugama i velikih očekivanja od mobilnih usluga, koja još uvijek nisu dovoljno istražena. Unatoč tomu, zbog svojih obilježja, poput ovisnosti o tehnologiji za vrijeme pružanja usluga, usluge mobilnoga bankarstva mogu kod korisnika izazvati visok stupanj percipiranoga rizika uporabe usluge. Iz tih razloga poslovne banke trebaju sve više ulagati u kvalitetu usluge mobilnoga bankarstva s ciljem stvaranja zadovoljstva korisnika i ispunjenja očekivanja korisnika te tako osigurati dugoročni odnos s korisnicima usluga. S namjerom utvrđivanja utjecaja percepcija kvalitete usluge mobilnoga bankarstva provedeno je istraživanje anketnim upitnikom na odabranom uzorku pripadnika generacije Z. Percipirana kvaliteta usluge mobilnoga bankarstva koncipirana je pomoću proširenoga i prilagođenoga modela E-S-Qual autora Parasuraman, Zeithaml i Malhotra (2005). Prikupljeni podaci analizirani su primjenom PLS-SEM metode i izradom matrice važnosti i performansi. Istraživanje je utvrdilo postojanje pozitivnoga i značajnoga utjecaja dimenzija dizajna i vizualne atraktivnosti, pouzdanosti, efikasnosti i nešto slabijega utjecaja dimenzije kvalitete informacija na zadovoljstvo korisnika pripadnika generacije Z. Analizom matrice važnosti i performansi dobivene su dodatne informacije o značaju pojedinih dimenzija i obilježja kvalitete usluge mobilnoga bankarstva. Prema rezultatima

analize matrice važnosti i performansi dimenzija dizajna kvalitete usluge mobilnoga bankarstva bila je važna za ostvarenje zadovoljstva, ali je ostvarila nižu razinu performansi. Navedena dimenzija ujedno predstavlja prioritet za poboljšanje kvalitete usluge mobilnoga bankarstva koje će u najvećoj mjeri doprinijeti zadovoljstvu korisnika pripadnika generacije Z. Iako su rezultati istraživanja pokazali da dimenzija sigurnosti usluge mobilnoga bankarstva nije važna za pripadnike generacije Z u formiranju zadovoljstva, analiza matrice važnosti i performansi na razini indikatora ukazala je na to da je korisnicima, pripadnicima generacije Z, ipak bila važna sigurnost korištene aplikacije mobilnoga bankarstva.

KLJUČNE RIJEČI: kvaliteta usluge mobilnoga bankarstva, zadovoljstvo korisnika, analiza važnosti i performansi, generacija Z

JEL classification: M31

UVOD

Ubrzani razvoj informacijsko-komunikacijske tehnologije, s jedne strane, te sve veća uporaba pametnih telefona i ostalih uređaja, s druge strane, omogućili su uslužnim poduzećima ponudu brojnih novih usluga novim kanalima distribucije. Poslovne banke u takvu razvojnu događaju nisu iznimka te se u sve većoj mjeri usmjeravaju prema razvoju i ponudi usluga mobilnoga bankarstva. Mobilno se bankarstvo odnosi na provođenje financijskih i nefinancijskih transakcija mobilnim telefonima i tabletima (Shaikh and Karjaluoto, 2015). Prema podacima Juniper Research (2020) 2020. godine oko 2,4 milijarde ljudi u svijetu koristilo se uslugama mobilnoga bankarstva te se predviđalo da će se 2024. godine takvim vrstama usluga koristiti oko 3,6 milijardi ljudi, odnosno 54 % više. Nadalje, prema istraživanju Hrvatske narodne banke (2020) u 2019. godini se oko 46 % hrvatskih građana koristilo mobilnim bankarstvom, dok je prosjek EU-a 58 %, s time da je u određenim zemljama, poput Danske i Nizozemske, taj postotak rastao na 90 %. Navedeno govori u prilog sve većem korištenju usluge mobilnoga bankarstva u budućnosti. Razlozi proizlaze iz brojnih koristi koje mobilno bankarstvo pruža korisnicima i poslovnim bankama. Mobilno bankarstvo omogućuje korisnicima korištenje raznih bankarskih usluga neovisno o prostoru i vremenu korištenja te uz niže troškove u odnosu na klasične bankarske usluge (Arcand *et al.*, 2017; Baabdullah *et al.*, 2019). Poslovne banke ponudom mobilnoga bankarstva smanjuju operativne troškove, šire ponudu svojih usluga te privlače nove korisnike i intenziviraju odnose s postojećim ko-

risnicima usluge (Tam i Olivera, 2016; Srinivas, 2014; Santini *et al.*, 2019). Mobilnim bankarstvom banke također lakše prikupljaju informacije o korisnicima usluge te im to poslije omogućuje bolju prilagodbu potrebama korisnika (Sahoo i Pillai, 2017). Ipak, ponuda i korištenje usluga mobilnoga bankarstva povezano je s određenim nedostacima. Usluga mobilnoga bankarstva zahtijeva određena ulaganja u informacijsko-komunikacijsku infrastrukturu banaka (Yuan *et al.*, 2016) te je još uvijek kod određenih korisnika prisutan visok stupanj percipiranoga rizika korištenja usluge vezan uz sigurnost korištenja usluge (Kamboj, Sharma i Sharmah, 2021), tehničke probleme s uslugom (Ladeira *et al.*, 2016) i niske efikasnosti usluge zbog maloga zaslona pametnoga telefona i teškoća u provođenju financijskih transakcija (Laukkanen, 2007), posebice starijih korisnika (Shams *et al.*, 2020) te straha od nefunkcioniranja usluge/aplikacije i nedobivanja potpunih i točnih informacija (Mostafa, 2020).

Sve navedeno zahtijeva neophodno ulaganje u kvalitetu usluge mobilnoga bankarstva s ciljem ostvarenja zadovoljstva korisnika i, s time povezano, dugoročnih odnosa. Kvaliteta usluge mobilnoga bankarstva i zadovoljstvo korisnika prepoznati su kao ključni čimbenici uspjeha i konkurentske prednosti za poslovne banke (Jun i Palacios, 2015; Sharma i Sharma, 2019; Arkhipova, 2022). Stoga je neophodno, radi utvrđivanja utjecaja kvalitete usluge mobilnoga bankarstva na zadovoljstvo, prethodno definirati kvalitetu usluge mobilnoga bankarstva, uzimajući u obzir obilježja ponašanja pojedinih segmenata korisnika. Dosadašnja istraživanja mobilnoga bankarstva, s obzirom na to da se radi o primjeni novih tehnologija u bankarstvu, bila su pretežito usmjerena na utvrđivanje čimbenika prihvaćenosti mobilnoga bankarstva pri čemu su uglavnom korišteni, uz određena proširenja raznim teorijskim konstruktima, TAM (Davis, 1989) i model UTUAT/UTUAT 2 (Venkatesh, Thong i Xu, 2012; Shaikh i Karjaluoto, 2015; Tam i Oliveira, 2016; Silanoi, Naruetharadhol i Ponsree, 2023; Shaikh *et al.*, 2022). Ipak, pojedini autori ističu potrebu istraživanja postfaze korištenja usluge, odnosno čimbenika koji utječu na namjeru ponovnoga korištenja usluge (Arcand *et al.*, 2017; Ashique i Rameshkumar, 2022). S druge strane, istraživanja kvalitete usluge mobilnoga bankarstva ukazuju na postojanje razlika u percepcijama pojedinih obilježja kvalitete usluge koje proizlaze iz kulturnoga okruženja (Jun i Palacios, 2016) i pojedinih sociodemografskih obilježja korisnika, i to posebice dobi i spola (Merhi *et al.*, 2020; Zainab, Rasheed i Imran, 2020; Ashique i Rameshkumar, 2022) što ujedno stvara temelje za detaljnije istraživanje percepcija kvalitete usluge pojedinih segmenata korisnika usluge, posebno generacije Z koja za poslovne banke predstavlja važan segment sadašnjih, ali dugoročno, uz primjereno ispunjenje očekivanja, i budućih segmenata korisnika usluge mobilnoga bankarstva.

U tom je smislu namjera ovoga rada analizirati i utvrditi utjecaj percepcije kvalitete usluge mobilnoga bankarstva na zadovoljstvo korisnika pripadnika generacije Z u Hrvatskoj. Generacija Z predstavlja trenutačno najveći izazov za marketing poslovnih organizacija jer se više koriste mobilnim uslugama u odnosu na druge generacije, ostvaruju sve veće prihode te njihova očekivanja prema uslugama, pa tako i mobilnoga bankarstva, nisu u dovoljnoj mjeri istražena (Priporas, Stylos i Fotiadis, 2017; Silanoi *et al.*, 2023). U skladu s time, u radu se nakon uvoda daje kratki pregled dosadašnjih istraživanja kvalitete usluge mobilnoga bankarstva i zadovoljstva, nakon toga prezentiraju se rezultati istraživanja međuovisnosti pojedinih dimenzija i obilježja kvalitete usluge mobilnoga bankarstva, koja utječe na zadovoljstvo korisnika, pripadnika generacije Z. Posebno se iznose i analiziraju matrice važnosti i performansi primjenom metode PLS-SEM. Na koncu je zaključak u kojem se, osim zaključnih razmatranja, iznose preporuke za marketinški menadžment i buduća znanstvena istraživanja u području kvalitete usluge mobilnoga bankarstva te ograničenja rada.

PREGLED LITERATURE

Generacija Z obuhvaća pojedince koji su rođeni nakon 1995. te do 2010. godine. Pripadnici navedene generacije smatraju se digitalnim domorocima jer su rođeni u razdoblju brzoga širenja pametnih telefona i uređaja te se smatra da imaju visok stupanj digitalne kompetencije i neovisnosti, otvoreni su prema poduzetništvu i različitostima (Silanoi, Naruetharadhol i Ponsree, 2023). Oni svoje osobne odnose razviju i njeguju pomoću raznih društvenih mreža i ostalih digitalnih kanala, brzo prikupljaju i razmjenjuju informacije te uče pomoću digitalnih medija. Pripadnici su navedene generacije kreatori (influenceri/utjecajnici) i korisnici raznih sadržaja koji se distribuiraju društvenim mrežama (Meffert *et al.*, 2019). S obzirom na sklonost prema tehnologiji pripadnici generacije Z u odnosu na ostale društvene skupine u relativno većem broju koriste se uslugama mobilnoga bankarstva (Ghoynaqi, 2022; Hameed i Nigam, 2022; Rithmaya, 2024). Tako se, primjerice, u SAD-u u 2021. godini 75 % pripadnika dobne skupine od 15 do 24 godine koristilo uslugama mobilnoga bankarstva, za razliku od 15 % korisnika dobne skupine iznad 65 godina. Prema kvalitativnom istraživanju (Shams *et al.*, 2020) pripadnici generacije Z očekuju od mobilnoga bankarstva prilagođenije korisničko sučelje aplikacije, primjenu jedne aplikacije za više različitih računa, omogućavanje međunarodnih transakcija, jače poticaje (nagrade) za uporabu mobilnih financijskih transakcija te jasnoću i lakoću korištenja aplikacije. Rahadi *et al.*

(2022) navode kako pripadnicima generacije Z nedostaje osnovnih znanja iz financijske pismenosti zbog pretjerane orijentacije na življenje u sadašnjosti, što posljedično može voditi do loših financijskih odluka, odnosno posebnih zahtjeva prema kvaliteti usluge mobilnoga bankarstva ili nekorištenja usluge. Navedene rezultate dijelom potvrđuje istraživanje Hrvatske poštanske banke (2021). Prema istraživanju oko trećina ispitanika pripadnika generacije Z ima cilj povećanje stabilnosti financija, preko trećine ispitanika smatra da će mobilno bankarstvo postati standard, a preko 10 % ispitanika očekuje da će mobilno bankarstvo postati njihov osnovni savjetnik, odnosno da će potpuno zamijeniti fizičke poslovnice. U tom je smislu, zbog sve većega značaja pripadnika generacije Z kao korisnika usluge mobilnoga bankarstva, za poslovne banke potrebno utvrditi i mjeriti koncept percipirane kvalitete usluge s aspekta korisnika pripadnika generacije Z kao ključnoga čimbenika u stvaranju zadovoljstva korisnika uslugom.

Percipirana kvaliteta usluge s aspekta korisnika predstavlja stupanj zadovoljenja potreba korisnika izvedbom usluge u odnosu na njegova očekivanja od usluge (Parasuraman, Zeithaml i Berry, 1988). Vezano uz navedenu definiciju kvalitete usluge Arcand *et al.* (2017) definiraju kvalitetu usluge kao ukupnu prosudbu korisnika usluge mobilnoga bankarstva o superiornosti izvedbe i obilježjima isporuke mobilnoga sadržaja. U znanstvenoj literaturi ne postoji opće prihvaćeni model, odnosno ljestvica za mjerenje kvalitete usluge mobilnoga bankarstva. Unatoč tomu pojedini autori ističu potrebu razvoja takvih ljestvica koje bi bile korisne znanstvenicima i praktičarima u budućim istraživanjima mobilnih financijskih usluga (Shaikh *et al.*, 2021). Naime, percipirana kvaliteta usluga ovisi o kontekstu pružanja usluge i vrsti same usluge (Jun i Palacios, 2016). Iz tih su razloga istraživači prilagođavali postojeće generičke ljestvice za mjerenje kvalitete usluge poput SERVQUAL (Parasuraman, Zeithaml i Berry, 1988) i SERVPERF (Cronin i Tylor, 1992) i ljestvice E-S-Qual (Parasuraman, Zeithaml i Malhotra, 2005) na usluge mobilnoga bankarstva. Od navedenih modela posebice je model E-S-Qual, koji je izvorno razvijen za *e-commerce* usluge i koje su relativno bliske mobilnim uslugama, u nešto većoj mjeri prilagodljiv za usluge mobilnoga bankarstva. Prema modelu E-S-Qual, koji se sastoji od 22 tvrdnje, percipirana kvaliteta e-usluga koje se isporučuju na mrežnim stranicama sastoji se od dimenzija *efikasnosti* (odnosi se na lakoću i brzinu pristupa i korištenja mrežne stranice), *ispunjenja* (stupanj ispunjenja obećanja o dostupnosti i isporuci proizvoda), *dostupnosti sustava* (tehnička ispravnost funkcioniranja mrežne stranice) i *privatnosti* (stupanj zaštite korisnikovih informacija koju pruža mrežna stranica). Isti su autori proširili model za mjerenje kvalitete oporavka usluge pomoću mrežne stranice (E-RecS-Qual) pomoću triju dodatnih dimenzija kvalitete: *responzivnost* (efikasno rješavanje problema na

mrežnoj stranici i povrat proizvoda), *kompensacija* (stupanj do kojega mrežna stranica nadoknađuje korisniku za probleme s uslugom) i *kontakt* (dostupnost i uslužnost osoblja za izravnu mrežnu podršku u rješavanju problema). Pojedini autori, poput Shankar *et al.* (2019), empirijskim istraživanjem nastojali su utvrditi prikladnost triju generičkih ljestvica za mjerenje kvalitete usluge mobilnoga bankarstva: SERVQUAL, SERVPERF i E-S-Qual. Autori su utvrdili da nijedan model nije potpuno prikladan za mjerenje kvalitete usluge mobilnoga bankarstva, ali ipak smatraju da su dimenzije kvalitete usluge *pouzdanost*, *sigurnost*, *empatija*, *efikasnost*, *ispunjenje* i *privatnost* ključne u objašnjavanju ukupne kvalitete usluge te pozivaju da se u budućim istraživanjima potvrde njihovi rezultati na drugim tržištima osim Indije. U tom smislu može se zaključiti da su navedeni modeli predstavljali temelj za koncipiranje kvalitete usluga mobilnoga bankarstva te su ujedno i najčešće korišteni modeli za utvrđivanje utjecaja kvalitete mobilnoga bankarstva na zadovoljstvo korisnika.

Odnos između kvalitete usluge i zadovoljstva već je godinama predmet istraživanja brojnih studija. Istraživanja potvrđuju pozitivnu vezu između percipirane kvalitete usluga i zadovoljstva za tradicionalne (Parasuraman, Zeithaml i Berry, 1988; Cronin i Taylor, 1992) i za izravne na mreži (Parasuraman, Zeithaml i Malhotra, 2005) mobilne usluge (Arcand *et al.*, 2017). Navedeno vrijedi i za usluge mobilnoga bankarstva. Ipak, razlike u studijama proizlaze iz korištenih modela kvalitete usluge mobilnoga bankarstva, odnosno odabranih dimenzija kvalitete uključenih u istraživanja. Jedno od prvih istraživanja (Chung i Kwon, 2009) utjecaja kvalitete usluge mobilnoga bankarstva na zadovoljstvo utvrdilo je značajan utjecaj dimenzija kvalitete sustava (brzina pružanja, pouzdanost, korisničko sučelje itd.) i dimenzije kvalitete informacija (razumljivost, potpunost i aktualnost pruženih informacija). S druge strane, istraživanje nije utvrdilo postojanje značajnoga utjecaja dimenzije kvalitete prezentacije informacija na zadovoljstvo korisnika. Ponešto drukčije rezultate donose Sharma i Sharma (2019) istražujući utjecaj dimenzija kvalitete usluge mobilnoga bankarstva i povjerenja na zadovoljstvo i namjeru korištenja usluge. Autori su utvrdili da su dimenzija kvalitete pratećih usluga (kvaliteta podrške korisnicima) i dimenzija kvalitete informacija imale pozitivan i značajan utjecaj na zadovoljstvo korisnika, dok dimenzija kvalitete sustava nije. Autori objašnjavaju navedene rezultate kulturološkim faktorima (istraživanje je provedeno u Omanu) te uzroke vide i u korisničkom korištenju uglavnom temeljnih funkcija mobilnih uređaja.

Arcand *et al.* (2017) kvalitetu usluge mobilnoga bankarstva promatrali su u dvije dimenzije: hedonističku i utilitarističku. Hedonistička dimenzija kvalitete obuhvaća dizajn, odnosno vizualnu atraktivnost aplikacije, društvenost i uživanje u korištenju usluge, a utilitaristička dimenzija obuhvaća sigurnost

i praktičnost u korištenju usluge. Rezultati istraživanja pokazali su značajan utjecaj svih dimenzija na zadovoljstvo korisnika, osim dimenzije dizajna.

Koristeći teorijski okvir Europskoga indeksa zadovoljstva, Poromatikul *et al.* (2019) percipiranu kvalitetu usluge mobilnoga bankarstva definirali su u pet tvrdnji koje su obuhvaćale aspekte pouzdanosti, preciznosti, sigurnosti i organiziranosti usluge te su utvrdili postojanje značajnoga utjecaja kvalitete na zadovoljstvo korisnika.

Inan *et al.* (2023) kvalitetu su usluge mobilnoga bankarstva definirali kroz dimenzije okruženja, interakcije i rezultata usluge. Autori su utvrdili, koristeći okvir teorije samoodređenja, direktan i indirektan utjecaj kvalitete usluge mobilnoga bankarstva na zadovoljstvo korisnika, izravno preko konstrukta kompetencija, autonomije i povezanosti korisnika s uslugom.

Orehovački, Blašković i Kurevija (2023) za hrvatsko tržište kvalitetu usluge mobilnoga bankarstva promatrali su u sljedećim dimenzijama: jednostavnost korištenja, efikasnost, kvaliteta povratnih informacija, reaktivnost, sigurnost i osobni podaci i korisnost. Autori su utvrdili pozitivan utjecaj pojedinih dimenzija kvalitete usluge mobilnoga bankarstva na zadovoljstvo i namjere ponašanja korisnika usluge.

Unatoč tomu što nema specifičnih istraživanja utjecaja kvalitete usluge mobilnoga bankarstva na zadovoljstvo korisnika pripadnika generacije Z, ipak se u postojećoj znanstvenoj literaturi mogu pronaći parcijalna istraživanja određenih dimenzija kvalitete usluge mobilnoga bankarstva. Istraživanja pokazuju da su pripadnici generacije Z posebno zabrinuti u pogledu sigurnosti korištenja usluge i zaštite osobnih podataka (Purwati *et al.*, 2018; Mulya i Yuhertiana, 2023) koje može voditi k nepovjerenju korisnika i nekorisćenju usluge. Nadalje, mlađim korisnicima usluge smeta pretjeran broj opcija i funkcija aplikacija za mobilno bankarstvo te traže besprijekorno, „glatko“ i interaktivno korištenje usluge, odnosno sučelja aplikacije (Sharma, 2024; Koenite, Maziriri i Chuchu, 2021). Istraživanja pokazuju i to da pripadnici generacije Z cijene pouzdanost i brzinu usluga mobilnoga bankarstva (Nguyen *et al.*, 2023). Shams *et al.* (2020) navode da pripadnici generacije Z žele prilagodljivu uslugu mobilnoga bankarstva i poboljšano sučelje aplikacije mobilnoga bankarstva.

Iz svega navedenoga može se zaključiti da je raznolik pristup u koncipiranju konstrukta percipirane kvalitete usluge mobilnoga bankarstva. Među analiziranim izvorima nije utvrđeno specifično istraživanje percepcija kvalitete usluge mobilnoga bankarstva koje se odnosi na generaciju Z, iako u većini istraživanja veći dio uzorka čine upravo pripadnici te generacije. U tom smislu predloženo istraživanje namjerava popuniti navedenu prazninu koristeći pritom prošireni i prilagođeni model kvalitete usluge E-S-Qual (Parasurman,

Zeithaml i Malhotra, 2005). Navedeni prošireni model obuhvaćat će sve faze procesa korisnikova korištenja usluge mobilnoga bankarstva: prosudbu aspekata vizualnih obilježja usluge, dostupnost usluge, lakoću korištenja usluge i uštedu korisnikovih resursa, kvalitetu pruženih informacija, važne aspekte digitalne sigurnosti usluge te interakciju s poslovnom bankom.

METODOLOGIJA I UZORAK ISTRAŽIVANJA

Za potrebe istraživanja percepcije kvalitete usluge i zadovoljstva uslugom mobilnoga bankarstva pripadnika generacije Z upotrebljen je strukturirani anketni upitnik. Istraživanje je provedeno u siječnju i veljači 2023. e-poštom. Ispitanici, pripadnici generacije Z u dobi od 18 do 24 godine, bili su studenti iz baze podataka Fakulteta ekonomije i turizma „Dr. Mijo Mirković“ autora rada. Ispitanici su e-poštom primili poveznicu na kojoj se nalazio upit te im je, uz molbu za popunjavanje upitnika, objašnjena svrha istraživanja i osigurana anonimnost odgovora. Upitnik se sastojao od tri dijela. Prvi dio odnosio se na navike korištenja mobilnoga bankarstva, drugi dio sadržavao je pitanja vezana uz percipiranu kvalitetu usluge i zadovoljstvo korisnika (Tablica 1.), a treći je dio pitanja obuhvaćao određene demografske podatke ispitanika. Upitnik je poslan na 220 e-adresa te je vraćeno 112 ispravno popunjenih upitnika ili 50,1 %. S obzirom na spol 68 % ispitanika bilo je ženskoga spola, a 32 % muškoga spola. Kao najviši završen stupanj obrazovanja srednju školu imalo je 25,9 % ispitanika, prijediplomski studij 49,1 % ispitanika, a završen diplomski studij imalo je 25 % ispitanika. Oko 2,7 % ispitanika uslugama mobilnoga bankarstva koristilo se kraće od 6 mjeseci, 7,1 % od 6 mjeseci do godine dana, 26 % ispitanika od 1 do 3 godine, a dulje od 3 godine mobilnim bankarstvom koristilo se 63,2 % ispitanika. S obzirom na učestalost korištenja, 25,89 % ispitanika koristilo se uslugama mobilnoga bankarstva manje od 3 puta tjedno, 47,3 % od 3 do 5 puta tjedno, 16,9 % od 6 do 10 puta tjedno, a 9,8 % ispitanika navedenim uslugama koristilo se više od 10 puta tjedno. Oko 24,1 % ispitanika koristilo se uslugama mobilnoga bankarstva Zagrebačke banke d. d., 23,2 % ispitanika Privredne banke d. d., 17,9 % ispitanika Erste & Steiermaerkische bank d. d., 17,9 % OTP banke, a preostali su se ispitanici koristili uslugama ostalih banaka. Ispitanici su se koristili sljedećim uslugama mobilnoga bankarstva: provjera stanja i promjena na računu (100 %), plaćanje računa (93 %), pristup uslugama internetskoga bankarstva (59 %), provjera tečajnih lista (35 %), kupnja raznih bonova (32 %), provjera dostupnosti poslovnica (radno vrijeme, pronalazak bankomata) (30 %), slanje sredstava u inozemstvo (18 %) i kontaktiranje s os-

obnim bankarom (14 %). Oko 60 % ispitanika aplikaciji mobilnoga bankarstva pristupalo je pomoću sustava Android, a oko 40 % pomoću Appleova iOS-a.

Ljestvica za mjerenje percipirane kvalitete usluge mobilnoga bankarstva utvrđena je na temelju sveobuhvatnoga pregleda znanstvene literature te je obuhvaćala 7 dimenzija kvalitete i 28 tvrdnja. Dimenzija kvalitete usluge mobilnoga bankarstva *efikasnost* obuhvaćala je 8 tvrdnja, dimenzija *dostupnost* aplikacije 4 tvrdnje, dimenzija *pouzdanost* 3 tvrdnje, dimenzija *sigurnost* i *privatnost* 3 tvrdnje, a preuzete su i prilagođene na temelju modela E-S-Qual autora Parasuraman, Zeithaml, i Malhotre (2005). Dimenzije *kvaliteta informacija*, koja je obuhvaćala 4 tvrdnje, i *kvalitete pratećih usluga*, koja je definirana s 3 tvrdnje, preuzete su i prilagođene prema Tam i Oliveira (2016), a dimenzija *dizajn / vizualna atraktivnost* definirana s 3 tvrdnje prilagođena je prema istraživanju Cyr *et al.* (2006). Konstrukt zadovoljstva korisnika mjeren je pomoću 4 tvrdnje, a preuzet je i prilagođen prema Taylor i Baker (1994) te Oliver (1980). Sve su tvrdnje mjerene Likertovom ljestvicom sa sedam intervala (1 – uopće se ne slažem, 7 – u potpunosti se slažem). Podaci su analizirani pomoću statističkoga paketa Stata 16 i SmartPLS-a (Ringle, Wende i Becker, 2024). U analizi podataka upotrebljena je deskriptivna statistička analiza te PLS analiza u okviru koje je provedena konfirmacijska faktorska analiza radi utvrđivanja pouzdanosti i valjanosti korištenih mjernih ljestvica kvalitete usluge mobilnoga bankarstva i zadovoljstva korisnika. Nakon konfirmacijske faktorske analize provedena je analiza strukturnoga modela radi utvrđivanja smjera i intenziteta smjera veze između istraživanih teorijskih konstrukata kvalitete usluge i zadovoljstva korisnika. Konačno, izrađena je analiza važnosti i performansi radi dobivanja detaljnijega uvida u utjecaj kvalitete usluge mobilnoga bankarstva na zadovoljstvo, i to na razini dimenzija kvalitete usluge i na razini indikatora. Analiza važnosti i performansi provedena je prema standardnome postupku u pet koraka (Ringle i Sarstedt, 2016): 1) provjera poštivanja pretpostavki analize, 2) izračun vrijednosti performansi, 3) izračun vrijednosti važnosti, 4) izrada matrice važnosti i performansi i 5) proširenje analize na razinu indikatora.

REZULTATI ISTRAŽIVANJA

PERCEPCIJA KVALITETE USLUGE MOBILNOGA BANKARSTVA I ZADOVOLJSTVA KORISNIKA PRIPADNIKA GENERACIJE Z

Pored utvrđivanja međuovisnosti percipirane kvalitete usluge mobilnoga bankarstva i zadovoljstva korisnika pripadnika generacije Z, nastojalo se utvrditi kako pripadnici generacije Z, pored ukupne razine, percipiraju pojedine

elemente kvalitete usluge mobilnoga bankarstva i zadovoljstva. Rezultati analize prikazani su u Tablici 1.

Tablica 1. Deskriptivna statistika

Tvrdnja	Naziv	Ar. sredina	St. dev.
Dizajn (npr. boje, animacije, pozadine itd.) aplikacije mobilnoga bankarstva moje banke je kreativan.	DIZ1	5,06	0,15
Dizajn (npr. boje, animacije, grafika, veličina fonta itd.) aplikacije mobilnoga bankarstva moje banke izgleda profesionalno.	DIZ2	5,80	0,13
Ukupno, dizajn aplikacije mobilnoga bankarstva moje banke je vizualno privlačan.	DIZ3	5,47	0,14
Aplikacija mobilnoga bankarstva moje banke je uvijek dostupna za obavljanje transakcija.	DOS1	5,99	0,12
Aplikacija mobilnoga bankarstva moje banke brzo se učitava te je odmah spremna za rad.	DOS2	6,01	0,12
Aplikacija mobilnoga bankarstva moje banke ne „ruši“ se ili naglo zatvori.	DOS3	4,98	0,20
Aplikacija mobilnoga bankarstva moje banke ne „zamrzne“ se kad želim obaviti neku transakciju.	DOS4	5,46	0,19
Aplikacija mobilnoga bankarstva moje banke omogućuje mi da lako nađem bankarsku uslugu ili informaciju koju tražim.	EF1	5,91	0,11
Aplikacija mobilnoga bankarstva moje banke omogućuje mi da brzo obavim transakcije.	EF2	6,50	0,08
Informacije u aplikaciji mobilnoga bankarstva moje banke dobro su organizirane.	EF3	5,80	0,12
Stranice u aplikaciji mobilnoga bankarstva moje banke brzo se učitavaju.	EF4	6,03	0,12
Aplikacija mobilnoga bankarstva moje banke jednostavna je za korištenje.	EF5	6,27	0,09
Navigacija kroz aplikaciju mobilnoga bankarstva moje banke dobro je napravljena.	EF6	5,90	0,12
Aplikacija mobilnoga bankarstva moje banke intuitivna je za korištenje.	EF7	5,69	0,12
Aplikacija mobilnoga bankarstva moje banke redovito se poboljšava ažuriranjima ili novim verzijama.	EF8	5,62	0,15
Informacije koje se pružaju uslugom mobilnoga bankarstva moje banke aktualne su.	INF1	6,04	0,10
Informacije koje se pružaju uslugom mobilnoga bankarstva moje banke lako su razumljive.	INF2	6,09	0,11

Tvrdnja	Naziv	Ar. sredina	St. dev.
Informacije koje se pružaju uslugom mobilnoga bankarstva moje banke potpune su.	INF3	6,10	0,10
Informacije koje se pružaju uslugom mobilnoga bankarstva moje banke točne su.	INF4	6,29	0,09
Transakcije se pomoću aplikacije mobilnoga bankarstva moje banke provode u vrijeme kada su obećane.	POUZ1	6,55	0,09
Transakcije su pomoću aplikacije mobilnoga bankarstva moje banke točno provedene.	POUZ2	6,66	0,08
Transakcije se pomoću aplikacije mobilnoga bankarstva moje banke provode u prikladnom vremenskom intervalu.	POUZ3	6,51	0,10
Osobni bankar / <i>Call centar</i> moje banke uvijek mi pomaže i daje podršku s uslugom mobilnoga bankarstva.	PRAT1	5,48	0,13
Osobni bankar / <i>Call centar</i> moje banke uvijek iskazuje osobitu pažnju kad ja imam probleme s uslugom mobilnoga bankarstva.	PRAT2	5,48	0,12
Osobni bankar / <i>Call centar</i> moje banke ima prikladno znanje i kompetencije da odgovori na sve moje upite u vezi s uslugom mobilnoga bankarstva.	PRAT3	5,74	0,12
Usluge mobilnoga bankarstva moje banke su sigurne (npr. pristup aplikaciji, potvrđivanje transakcija i sl.).	PRIV1	6,48	0,08
Moji osobni podaci i podaci o mojim financijskim transakcijama ne dijele se pomoću aplikacije mobilnoga bankarstva moje banke trećim osobama/poduzećima.	PRIV2	6,16	0,12
Aplikacija mobilnoga bankarstva moje banke štiti informacije o mojim financijskim transakcijama i kreditnim karticama.	PRIV3	6,25	0,10
UKUPNA KVALITETA USLUGE		5,81	0,53
Sretan sam uslugom mobilnoga bankarstva moje banke.	ZAD1	6,35	0,09
Zadovoljan sam aplikacijom mobilnoga bankarstva moje banke.	ZAD2	6,35	0,09
Sveukupno, zadovoljan sam mojom bankom.	ZAD3	6,23	0,10
Odluka da koristim usluge mobilnoga bankarstva moje banke bila je mudra.	ZAD4	6,43	0,10
UKUPNO ZADOVOLJSTVO		6,34	0,07

Izvor: autorov izračun, n = 112

Prema rezultatima deskriptivne analize može se zaključiti da su pripadnici generacije Z u prosjeku najbolje cijenili sljedeća obilježja percipirane kvalitete usluga mobilnoga bankarstva: 1) POUZ2 – *Transakcije su pomoću aplikacije*

mobilnoga bankarstva moje banke točno provedene. ($X^- = 6,66$); 2) POUZ1 – *Transakcije se pomoću aplikacije mobilnoga bankarstva moje banke provode u vrijeme kada su obećane.* ($X^- = 6,55$); 3) POUZ3 – *Transakcije se pomoću aplikacije mobilnoga bankarstva moje banke provode u prikladnom vremenskom intervalu.* ($X^- = 6,51$); 4) EF2 – *Aplikacija mobilnoga bankarstva moje banke omogućuje mi da brzo obavim transakcije.* ($X^- = 6,50$); i 5) PRIV1 – *Usluge mobilnoga bankarstva moje banke su sigurne (npr. pristup aplikaciji, potvrđivanje transakcija i sl.).* ($X^- = 6,48$). S druge strane, pripadnici generacije Z najniže su ocjene dali sljedećim varijablama kvalitete: 1) DOS3 – *Aplikacija mobilnoga bankarstva moje banke se ne „ruši“ ili naglo zatvori.* ($X^- = 6,93$); 2) DIZ1 – *Dizajn (npr. boje, animacije, pozadine itd.) aplikacije mobilnoga bankarstva moje banke je kreativan.* ($X^- = 5,06$); 3) DOS4 – *Aplikacija mobilnoga bankarstva moje banke se ne „zamrzne“ kad želim obaviti neku transakciju.* ($X^- = 5,46$); 4) DIZ3 – *Ukupno, dizajn aplikacije mobilnoga bankarstva moje banke vizualno je privlačan.* ($X^- = 5,47$); i 5) PRAT1 – *Osobni bankar / Call centar moje banke uvijek mi pomaže i daje podršku s uslugom mobilnoga bankarstva.* ($X^- = 5,48$).

Pripadnici generacije Z najbolje su ocijenili određene elemente pouzdanosti usluge mobilnoga bankarstva, brzinu i sigurnost pružanja usluge, a nešto su niže ocjene dobili aspekti dizajna aplikacije mobilnoga bankarstva, odnosno prateće usluge te dostupnost usluge. Općenito, ispitanici su ukupnu kvalitetu usluge mobilnoga bankarstva ocijenili pozitivno ($X^- = 5,81$, $t = 27,87$; $p < 0,05$) te je navedena vrijednost bila statistički značajno različita od neutralne vrijednosti na korištenoj ljestvici (4). Također, pripadnici su zadovoljni pruženim uslugama mobilnoga bankarstva ($X^- = 6,34$, $t = 30,90$; $p < 0,05$) čija je prosječna ocjena ukupnoga zadovoljstva bila statistički značajno različita od 4, odnosno srednje vrijednosti korištene mjerne ljestvice.

ANALIZA MEĐUOVISNOSTI KVALITETE USLUGE MOBILNOGA BANKARSTVA I ZADOVOLJSTVA KORISNIKA

Za utvrđivanje međuovisnosti između pojedinih dimenzija kvalitete usluge mobilnoga bankarstva i zadovoljstva korisnika upotrebljena je PLS metoda analize strukturnih jednadžba. PLS metoda odabrana je jer omogućuje procjenu modela na manjim uzorcima te je cilj predmetnoga istraživanja u osnovi prediktivnoga karaktera, a ne testiranje teorija. Pored toga, PLS metoda u osnovi je neparametarska metoda koja omogućuje dobivanje prikladnih rezultata i u uvjetima kada pretpostavke primjene određenih analiza, poput normalne dis-

tribucije varijabla, nisu potpuno poštovane (Hair *et al.*, 2022). Prije utvrđivanja smjera i jačine veze između percipiranih dimenzija kvalitete usluge mobilnoga bankarstva provedena je procjena pouzdanosti i valjanosti upotrebljenih mjernih ljestvica, a provedena je konfirmacijskom faktorskom analizom.

Svi konstrukti uključeni u analizu koncipirani su sukladno sličnim prethodnim istraživanjima kao reflektivni konstrukti. Na temelju dobivenih rezultata može se zaključiti da su korišteni indikatori pouzdani te mjerne ljestvice iskazuju zadovoljavajuću razinu konvergentne valjanosti. Veličina faktorskih opterećenja prelazila je vrijednost od 0,7 te su bili statistički značajni ($p < 0,05$), osim za indikatore DOS2, DOS3, EF1, EF2 i ZAD4, ali s obzirom na to da su navedena faktorska opterećenja bila iznad 0,6 te njihovim micanjem nije došlo do značajnoga povećanja pokazatelja C. R. i AVE, oni su zadržani za sljedeće analize. C. R. pokazatelji kretali su se u rasponu od 0,79 do 0,94 i bili su veći od preporučene vrijednosti od 0,7. AVE pokazatelji kretali su se u rasponu od 0,55 do 0,89 i bili su veći od preporučene vrijednosti od 0,5 (Hair *et al.*, 2022). Nadalje, diskriminacijska valjanost testirana je pomoću kriterija Fornell i Larcker (1981) te izračunom HTMT indikatora.

Prema rezultatima analize korijeni AVE indikatora za sve konstrukte bili su veći od korelacija između pojedinih konstrukata čime je zadovoljen kriterij Fornell i Larcker, dok su se svi HTMT indikatori za sve parove konstrukata kretali u rasponu od 0,28 do 0,8 te bili niži od preporučene vrijednosti od 0,85. Na temelju navedenih rezultata može se utvrditi postojanje zadovoljavajuće razine diskriminacijske valjanosti te se može pristupiti analizi strukturnoga modela. Za procjenu modela upotrebljena je metoda *Bootstrapping* na 10 000 poduzoraka. Rezultati analize strukturnoga modela prikazani su u Tablici 2.

Tablica 2. Strukturni model percipirane kvalitete mobilnoga bankarstva i zadovoljstva

Veza	β – standardizirani koeficijent	St. dev.	t-vrijednost	f ²
DIZAJN -> ZADOVOLJSTVO	0,189*	0,079	2,40	0,06
DOSTUPNOST -> ZADOVOLJSTVO	0,022	0,102	0,22	0,001
EFIKASNOST -> ZADOVOLJSTVO	0,320*	0,098	3,27	0,09
KVALITETA_INF -> ZADOVOLJSTVO	0,203**	0,109	1,86	0,05
KV_USLUGE -> ZADOVOLJSTVO	0,042	0,063	0,67	0,004
POUZDANOST -> ZADOVOLJSTVO	0,186*	0,093	2,01	0,05
PRIVATNOST -> ZADOVOLJSTVO	0,067	0,089	0,74	0,007

Izvor: autorov izračun, n = 112, *p < 0,05, **p < 0,10

Na temelju rezultata analize strukturnoga modela može se zaključiti da su na zadovoljstvo korisnika pripadnika generacije Z statistički značajan i pozitivan utjecaj ($p < 0,05$) imale redom dimenzije *efikasnosti* ($\beta = 0,320$), *dizajna / vizualne atraktivnosti* ($\beta = 0,189$) i *pouzdanosti* ($\beta = 0,186$). Dimenzija *kvalitete informacija* imala je pozitivan i statistički značajan utjecaj na razini od 10 % signifikantnosti ($\beta = 0,203$). Općenito, navedeni utjecaji bili su maloga efekta (f^2 oko 0,05) za sve statistički značajne dimenzije kvalitete usluge mobilnoga bankarstva. Model je pomoću navedenih dimenzija općenito dobro objašnjavao zadovoljstvo korisnika ($R^2 = 0,63$) te je imao prikladnu razinu prediktivne valjanosti: Q^2_{predict} vrijednost iznosila je 0,56, dok su RMSE pokazatelji za sve indikatore konstrukta zadovoljstva bili manji od pripadajućih LM pokazatelja. Detaljnija objašnjenja rezultata istraživanja daju se u poglavlju Teorijski doprinos i praktične implikacije istraživanja.

ANALIZA VAŽNOSTI I PERFORMANSI USLUGE MOBILNOGA BANKARSTVA

Radi dobivanja dodatnih informacija o utjecaju kvalitete usluge mobilnoga bankarstva na zadovoljstvo korisnika, posebno na razini pojedinačnih varijabla kvalitete, provedena je analiza pomoću PLS metode i analiza važnosti i performansi (IPA analiza). IPA analiza dosad je korištena u različitim područjima, poput turizma, usluga pripremanja hrane, usluga obrazovanja, zdravstva, bankarstva itd. (Sever, 2014). Cilj je IPA analize utvrditi područja usluge koja su korisnicima važna, a ujedno ostvaruju loše performanse, čime se menadžmentu daju korisne informacije o potrebnim promjenama u cilju poboljšanja usluge. Primjena PLS tehnike daje prednosti u odnosu na klasičnu IPA analizu pomoću regresijske analize i korištenja sumarnih ljestvica kod kojih se pretpostavlja jednaka važnost varijabla indikatora, što uvodi pristranost u dobivenim rezultatima (Hair *et al.*, 2021).

IPA analiza stavlja u odnos nestandardizirane ukupne efekte utjecaja konstrukata, odnosno indikatora na ciljani konstrukt, koji predstavljaju relativnu važnost u objašnjenju ciljanoga konstrukta zajedno s vrijednostima latentne varijable koje predstavljaju performanse pojedinih konstrukata. Na taj način moguće je klasificirati dimenzije i obilježja kvalitete usluge mobilnoga bankarstva u 4 skupine prioriteta prema utjecaju na zadovoljstvo korisnika ovisno o tome nalazi li se dimenzija, odnosno obilježje kvalitete usluge, ispod ili iznad prosjeka (Martilla i James, 1977; Hair *et al.*, 2018), i to: 1) niska važnost – niske performanse (obilježja niskoga prioriteta), 2) niska važnost – visoke performanse (prekomjerne performanse), 3) visoka važnost – niske performanse (obilježja na koja se potrebno koncentrirati), i 4) visoka važnost – visoke performanse (obilježja o kojima se potrebno nastaviti brinuti kao do sada). U Tablici 3. prikazani su rezultati IPA analize, dok su na slikama 1. i 2. grafički prikazani odnosi između važnosti i performansi za pojedine dimenzije i obilježja kvalitete usluge mobilnoga bankarstva.

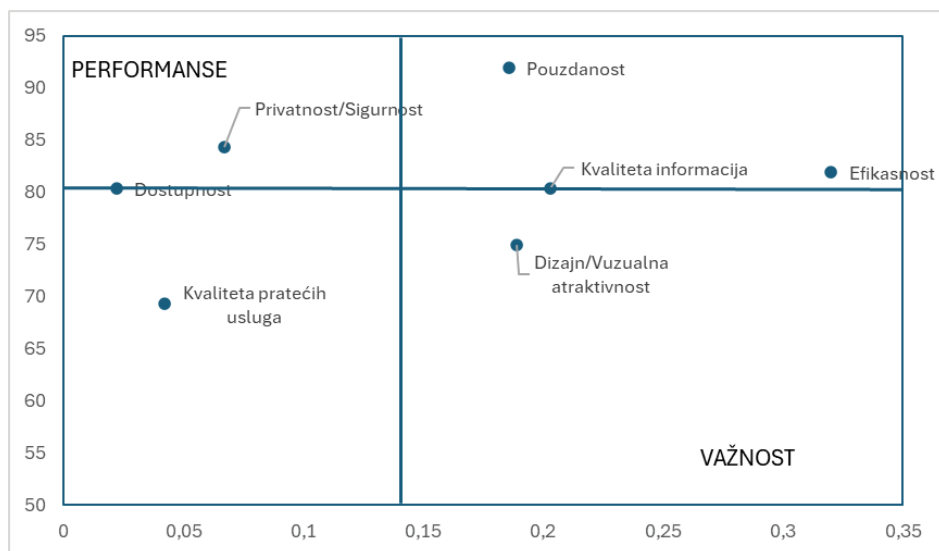
Tablica 3. Vrijednosti ukupnih efekata / važnosti i performansi na razini dimenzija kvalitete i zadovoljstva

Naziv	Ukupni efekt (Važnost)	Performanse
Dizajn / Vizualna atraktivnost	0,189	74,93
Dostupnost	0,022	80,33
Efikasnost	0,320	81,88
Kvaliteta informacija	0,203	80,34
Kvaliteta usluge	0,042	69,26
Pouzdanost	0,186	91,94
Privatnost/Sigurnost	0,067	84,36
Prosjek	0,147	80,43
DIZ1	0,055	67,71
DIZ2	0,071	80,06
DIZ3	0,084	74,55
DOS1	0,009	83,19
DOS2	0,009	83,48
DOS3	0,004	66,37
DOS4	0,006	74,26
EF1	0,039	78,21
EF2	0,053	87,50
EF3	0,066	80,06
EF4	0,050	83,78
EF5	0,050	85,36
EF6	0,047	81,70
EF7	0,053	78,27
EF8	0,067	76,93
INF1	0,056	80,71
INF2	0,053	81,79
INF3	0,076	77,46
INF4	0,056	82,37
PRAT1	0,018	69,64
PRAT2	0,014	69,64
PRAT3	0,015	68,53
POUZ1	0,064	92,56
POUZ2	0,063	91,52
POUZ3	0,071	91,82
PRIV1	0,041	82,74
PRIV2	0,020	86,01
PRIV3	0,021	87,50
Prosjek	0,044	80,13

Izvor: autorov izračun

Prema rezultatima IPA analize na razini dimenzija može se iz Tablice 1. i iz Slike 1. uočiti kako dimenzija *dizajna / vizualne atraktivnosti* ima visoku važnost za stvaranje zadovoljstva korisnika pripadnika generacije Z, ali i nižu razinu performansi u odnosu na prosjek te predstavlja područje usluge mobilnoga bankarstva koje je potrebno poboljšati. S druge strane, hrvatskim pripadnicima generacije Z važne su dimenzije kvalitete *pouzdanosti*, *efikasnosti* i *kvalitete informacija* te je ujedno i njihova performansa, osim za kvalitetu informacija, nešto viša od prosjeka. Manje su važne, ali imaju prema procjeni pripadnika generacije Z visoku razinu performansi, dimenzije kvalitete *dostupnosti* te *privatnosti i sigurnosti*. *Kvaliteta pratećih usluga* imala je nižu razinu performansi, ali i nisku važnost za pripadnike generacije Z (Slika1.).

Slika 1. Matrica važnosti i performansi: razina dimenzija kvalitete usluge mobilnoga bankarstva

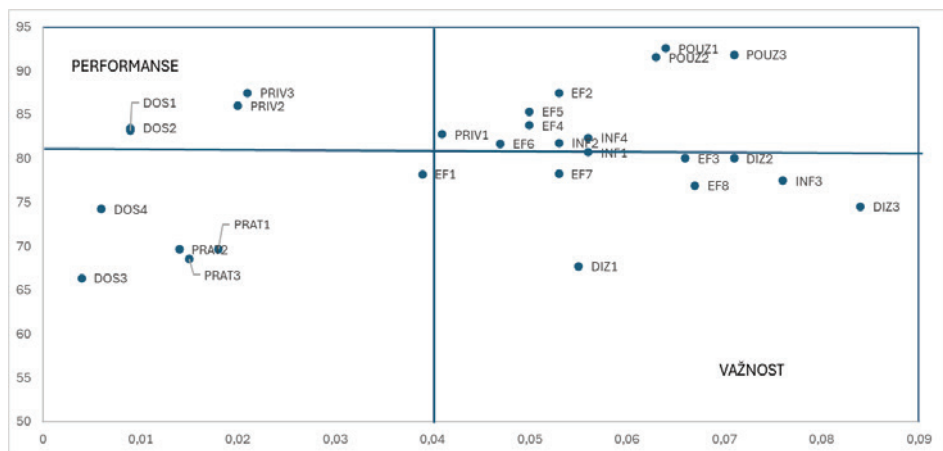


Izvor: autorova izrada

Detaljniji zaključci naziru se i promatranjem rezultata IPA analize na razini varijabla indikatora prikazanih na Slici 2. Varijable kvalitete koje se odnose na područje visoke važnosti, ali lošije performanse, na koje se menadžment posebno mora usmjeriti, odnose se na sve varijable dimenzije *dizajna / vizualne atraktivnosti* aplikacije mobilnoga bankarstva (DIZ1, DIZ2 i DIZ3), tri varijable dimenzije *efikasnosti* (EF3, EF7 i EF8), koje obuhvaćaju orga-

niziranost informacija unutar aplikacije, intuitivnost korištenja aplikacije te redovito ažuriranje aplikacije mobilnoga bankarstva, te jedne varijable dimenzije *kvalitete informacija*, koja se odnosi na potpunost pruženih informacija.

Slika 2. *Matrica važnosti i performansi: razina indikatora kvalitete usluge mobilnoga bankarstva*



Izvor: autorova izrada

S obzirom na ostale varijable kvalitete rezultati uglavnom prate rezultate ostvarene na razini dimenzija. Varijable koje su se odnosile na dimenzije *privatnosti/dostupnosti* pripadnicima generacije Z bile su manje važne. Jedino je varijabla PRIV1, koja se odnosi na opću percepciju sigurnosti korištenja aplikacije mobilnoga bankarstva, za korisnike bila važna te su ostvarili veću razinu performansi varijable DOS3 i DOS4 koje se odnose na zamrzavanje i rušenje aplikacije mobilnoga bankarstva. Sve varijable *kvalitete pratećih usluga* nisu bile važne za pripadnike generacije Z, ali su ostvarile nižu razinu performansi zbog čega predstavljaju moguće područje poboljšanja kvalitete usluge s ciljem zadržavanja postojeće razine korisnika.

TEORIJSKI DOPRINOS RADA I PRAKTIČNE IMPLIKACIJE ISTRAŽIVANJA

Provedeno istraživanje daje nekoliko teorijskih doprinosa. Prvo, istraživanje percepcija kvalitete usluge mobilnoga bankarstva odnosi se na fazu nakon

adopcije usluge koja je u prethodnim istraživanjima relativno manje istražena u odnosu na istraživanja čimbenika adopcije usluge mobilnoga bankarstva (Mostafa, 2020). Drugo, istraživanjem su analizirane percepcije pojedinih dimenzija kvalitete usluge mobilnoga bankarstva korisnika pripadnika generacije Z te je utvrđen njihov pozitivan utjecaj na zadovoljstvo korisnika u kontekstu hrvatskoga okruženja, odnosno okruženja razvijene zemlje, dok se velik broj prethodnih istraživanja usluga mobilnoga bankarstva odnosio na zemlje u razvoju, poput Indije, Pakistana, Libanona itd. (Banarjee i Sreejesh, 2022). Istraživanjem je utvrđen pozitivan utjecaj dimenzija *efikasnosti*, *pouzdanosti*, *kvalitete informacija* i *dizajna aplikacije* mobilnoga bankarstva na zadovoljstvo korisnika. Navedeni rezultati u skladu su s prethodnim istraživanjima utjecaja kvalitete usluge mobilnoga bankarstva (Arcand *et al.*, 2017; Sharma i Sharma, 2019; Poromatikul *et al.*, 2020), ali i sa specifičnim istraživanjima percepcija pojedinih aspekata kvalitete usluge iz perspektive pripadnika generacije Z, koji ističu da pripadnici generacije Z zbog svoga životnog stila zahtijevaju brze, pouzdane, efikasne, dobro organizirane i vizualno privlačne, odnosno prilagodljive usluge mobilnoga bankarstva (Sharma, 2024; Nguyen *et al.*, 2023; Koenait, Maziriri i Chuchu, 2021; Shams *et al.*, 2020). Istraživanje je potvrdilo prihvatljivost proširenoga modela E-Squal (Parasuraman, Zeithaml i Malhotra, 2005) i njegovu primjenu u koncipiranju percipirane kvalitete usluge mobilnoga bankarstva u sedam dimenzija kvalitete za segment korisnika pripadnika generacije Z. U tom smislu navedeni model pruža osnovu za buduća istraživanja utjecaja kvalitete usluge mobilnoga bankarstva na ostale važne konstrukte ponašanja korisnika, poput lojalnosti i povjerenja korisnika. Konačno, provedenom analizom važnosti i performansi utvrđena je važnost pojedinih dimenzija i obilježja kvalitete usluge mobilnoga bankarstva u odnosu na izvedbu i njihovu ulogu u oblikovanju zadovoljstva korisnika. Tako su prema rezultatima analize dimenzije i obilježja kvalitete dimenzija *pouzdanosti*, *efikasnosti* te *kvaliteta informacija* pripale grupi visoka razina performansi i visoka važnost, dok je druga značajna dimenzija *dizajna* pripala grupi visoke važnosti, ali slabih performansi.

Rezultati istraživanja nisu sasvim u skladu s istraživanjima ostalih autora (Purwati *et al.*, 2018; Poromatikul *et al.*, 2019; Shams *et al.*, 2020; Orehovački, Blašković i Kurevija, 2021; Mulya i Yuhertiana, 2023), vezano uz dimenziju *sigurnosti* kvalitete usluge mobilnoga bankarstva kod koje u ovom istraživanju nije utvrđena značajna veza sa zadovoljstvom korisnika. Navedeno se može objasniti korištenim uzorcima u navedenim istraživanjima, koji nisu obuhvaćali samo pripadnike generacije Z već i starije generacije koje su manje sklone novim tehnologijama te je kod njih percipirani rizik, vezan uz sigurnost

korištenja aplikacije i zaštitu podataka, više izražen. Ipak, u provedenom istraživanju kod analize matrice važnosti i performansi na razini indikatora (PRIV1) za pripadnike generacije Z ukupna sigurnost korištenja aplikacije bila je vrlo važna. Osim toga, razlike u rezultatima mogu se objasniti razlikama u percepcijama i svijesti rizika hrvatskih pripadnika generacije Z u odnosu na ostala okruženja te razlikama u razdoblju provođenja pojedinih istraživanja. Naime, kontinuiran tehnološki razvoj vodi prema sve sigurnijim aplikacijama za korisnika (npr. novi načini autentifikacije, ograničenja i potvrđivanje transakcija itd.). Navedene razlike u rezultatima pojedinih istraživanja iziskuju dodatna međukulturna istraživanja na većim uzorcima.

Provedeno istraživanje ima i određene praktične implikacije za marketinški menadžment poslovnih banaka. Poslovne banke s ciljem ispunjenja očekivanja pripadnika generacije Z trebale bi kontinuirano poboljšavati dizajn svojih aplikacija (npr. izgled, veličina fonta, boje, atraktivan vizualan prikaz infografike financijskih stanja itd.) te omogućiti korisnicima prilagodbu sučelja. Pri tome se može upotrijebiti, primjerice, analiza Conjoint radi utvrđivanja dizajna koji bi korisnicima dao najveću korist. U tom bi smislu bilo potrebno poboljšati intuitivnost, jednostavnost korištenja i organizaciju aplikacije mobilnoga bankarstva izbacivanjem suvišnih opcija i funkcija koje generaciji Z nisu potrebne te je redovito ažurirati. Nadalje, pripadnicima generacije Z potrebno je osigurati potpune i lako dostupne informacije o financijskim uslugama koje se odnose na ulaganje, prijenos i štednju financijskih sredstava, ali prilagođene njihovoj razini financijske pismenosti. Radi poboljšanja percepcije kvalitete usluge kod pripadnika generacije Z bilo bi potrebno organizirati određene videoedukacije ili videovodiče u korištenju usluge pomoću aplikacije mobilnoga bankarstva, ali i pomoću različitih društvenih mreža i *influencera*, u koje pripadnici generacije Z imaju povjerenje. Nadalje, neophodno je da poslovne banke kontinuirano ulažu i prate nove tehnologije poput umjetne inteligencije u cilju osiguranja pružanja inovativnih, sigurnih i bespriječnih usluga mobilnoga bankarstva prilagođenih potrebama generacije Z. S ciljem ispunjenja korisnikovih očekivanja od pojedinih elemenata usluge mobilnoga bankarstva neophodna su redovita istraživanja kvalitete usluge i zadovoljstva korisnika uslugom mobilnoga bankarstva.

ZAKLJUČAK

Mobilno bankarstvo pruža korisnicima brojne prednosti koje se odnose na neovisnost o vremenu i prostoru korištenja, odnosno pružanja usluge,

dostupnosti usluge, lakoće korištenja te postaje sve popularnije među pripadnicima generacije Z. Također, poslovnim bankama pružanje usluge mobilnoga bankarstva smanjuje troškove poslovanja, olakšava uspostavljanje i održavanje odnosa s postojećim i novim korisnicima, lakše uvođenje novih usluga te, stoga, predstavlja važan strateški resurs ostvarenja konkurentске prednosti i profitabilnosti. U tom smislu poslovne banke trebaju kontinuirano ulagati u kvalitetu usluge mobilnoga bankarstva radi stvaranja zadovoljnih i lojalnih korisnika usluge, posebno među pripadnicima generacije Z koji su skloniji brzim i stalnim promjenama.

Provedeno istraživanje utjecaja kvalitete mobilnoga bankarstva utvrdilo je značajan pozitivan utjecaj dimenzija *kvalitete dizajna*, *pouzdanosti*, *efikasnosti* te nešto slabiji utjecaj dimenzije *kvalitete informacija* na zadovoljstvo korisnika. Navedene rezultate dodatno je potvrdila analiza matrice važnosti i performansi na razini dimenzija i na razini obilježja kvalitete. Sve varijable dimenzije *dizajna* bile su važne za korisnike pripadnike generacije Z, ali su ostvarile nižu razinu performansi.

S ciljem ispunjenja očekivanja korisnika usluge, pripadnika generacije Z, poslovne banke trebaju osigurati pružanje brzih, pouzdanih, dobro organiziranih, sigurnih, jednostavnih za korištenje i vizualno atraktivnih, korisniku prilagođenih usluga mobilnoga bankarstva. Možemo očekivati da će u budućnosti na pružanje usluge mobilnoga bankarstva i marketinške strategije poslovnih banaka uvelike utjecati promjene tehnologije, poput primjene umjetne inteligencije u pružanju usluge mobilnoga bankarstva.

Provedeno istraživanje ima i određenih ograničenja koja ujedno mogu biti i podloga za buduća istraživanja. Prvo, uzorak pripadnika generacije Z bio je relativno mali i obuhvaćao je studente jednoga fakulteta te bi veći uzorak, koji obuhvaća širu populaciju pripadnika generacije Z, dao rezultate koji se u većoj mjeri mogu generalizirati. Nadalje, PLS modelom testiran je linearni odnos između kvalitete usluge mobilnoga bankarstva i zadovoljstva korisnika te bi se u budućim istraživanjima rezultati mogli proširiti testiranjem nelinearnosti veza između pojedinih konstrukata.

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DATA THREAT, SOCIAL MEDIA AND SMARTPHONE USAGE SHAPING THE AD TRANSPARENCY PERCEPTIONS

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In today's digital world, the use of social media and smartphones is widespread, which has changed the way customers interact with brands. Social media users do not realize how much time they spend on these media and how much personal data they leave behind, which the platforms collect. This large amount of personal data is available to companies and brands, giving them the opportunity to promote their products to a personalized and tailored audience.

The aim of this study is to investigate the relationships between the perceptions of data threat, smartphone usage, social media activity and consumer attitudes towards the transparency of advertising practices.

The methodology of this paper consists of a theoretical systematization and analysis of previous literature, as well as primary research based on a structured online questionnaire developed from previous studies and adapted to the objectives of this study. The data was collected from 497 active users of different social media platforms in Croatia. The collected data was empirically tested and validated using Partial Least Squares Structural Equation Modelling (PLS-SEM).

The results show that the perception of data threat plays an important role in influencing ad transparency, which implies that consumers evaluate the risks and benefits of data sharing. Social media engagement was also found to be a critical factor, with higher usage correlating with greater awareness and informed attitudes towards data practices. Despite expressing concern about their privacy, consumers continue to partici-

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pate in digital activities that expose their data. This highlights the fact that concern for their privacy goes hand in hand with their desire for personalized experiences, underlining the aspects of the privacy-paradox theory. In contrast, smartphone usage, although ubiquitous, did not show a significant direct impact on perceptions of advertising transparency, suggesting that habitual device use does not necessarily lead to reflective consumer behavior.

This study contributes to both theory and practice. The practical contribution of the study is that it provides a better understanding of the social media users' behavioral intentions, which can help marketers develop effective digital marketing strategies. In order to gain consumer trust, companies need to improve their communication about data usage and offer better control mechanisms. By promoting transparency, brands can build a stronger relationship with their audience.

Keywords: *Ad transparency, smartphone usage, social media activity, consumer privacy, data threat*

JEL classification: *M30, M31, 010*

INTRODUCTION

In the age of the Internet and related information and communication technologies, marketers have the opportunity to use numerous online channels to communicate with consumers. Today, global digital advertising spend exceeds \$601 billion (Lebow, 2023) and includes advertising displayed in various website segments, search advertising, social media advertising, and mobile advertising. Although this type of marketing communication is becoming increasingly popular, it fails to connect with consumers (Simola et al., 2013; Goldfarb & Tucker, 2011). In order to achieve a connection at the individual level, companies customize their communications, relying on detailed customer data (Murthi & Sarkar, 2003; Aguirre et al., 2016) which can be collected through covert or overt methods (Sundar and Marathe, 2010). A person's digital identity combines various offline characteristics with online profiles, relationships, preferences, and behaviors that together form their identity (Wessels 2012). Today, digital consumers are not completely anonymous, as almost all forms of communication and online activities generate data that can be collected and analyzed by third parties with or without consumers' consent. Customer information is collected at every moment of engagement, i.e. at every interaction

between consumers and organizations (Aguirre et al., 2016). The abundance of data collected from Internet users also allows brands to personalize their communication strategies in ways that were not possible before the era of the Internet and mobile technology (Rafieian & Yoganarasimhan, 2021).

Explicit data collection occurs when customers know that their data is being collected in real time. However, the boundaries of explicit consent can be blurred when companies silently record customer interactions. Companies can also silently collect data about a consumer's browsing history and location. When consumers respond to ads on social media, companies collect information about the customers themselves and their network connections. Companies can access details about a user's location, device type, mobile browsing and purchasing habits when they read mobile ads. Therefore, data collection may raise concerns among customers (Aguirre et al., 2015; Bulgurcu et al., 2010). Due to numerous instances of companies collecting data without clear justification or transparency, consumers adhere to strict boundaries and refuse to share their personal information (Karwatzki et al., 2017). Nevertheless, consumers might be willing to share their personal information with companies if they are promised benefits (Culnan & Bies, 2003; Chellappa & Shivendu, 2007; Sheng, Nah & Siau, 2008).

The personalization-privacy paradox (Awad & Krishnan, 2006) analyzes instances when personalized communication efforts by companies can have dual effects on consumer engagement. On the one hand, personalization can increase consumer interest and interaction with the company. However, when personalized communications raise privacy concerns about the collection and use of their personal information, it is likely to decrease engagement. This paradox ultimately determines the outcomes of personalized communications, which have a significant impact on the overall success of organizations (Dinev, 2014). As van Doorn and Hoekstra (2013) noted, increasing personalization efforts can lead to an increased sense of intrusiveness and can negatively impact consumer purchase intent. While offering discounts does not fully offset these negative effects, ads that are closely aligned with consumers' current needs can partially mitigate them. However, as the degree of intrusiveness increases, the positive impact of tailored advertising decreases.

The use of smartphones for various purposes during the day has become mainstream in the last decade (Vitezić & Perić, 2021; Elahi et al., 2019) and the frequent use of smartphones leads to a habit (Venkatesh et al., 2012). The usage of smartphones has increased the presence of individuals on social media, where they can publicly share user-generated content. On social media, people willingly and consciously share their information and data, which can

be referred to as online self-disclosure (Shih, Lai & Cheng, 2017). Individuals share their confidential details or personal preferences with others through online platforms, either for economic gain or to seek social support (Shih, Lai & Cheng, 2017).

Ad personalization involves viewing customers as individuals and tailoring ads to their preferences and inclinations (Bleier & Eisenbeiss, 2015). These personalized ads include product suggestions (Awad & Krishnan, 2006), social media promotions (Keyzer, Dens & Pelsmacher, 2015), and banner and mobile ads (Bang & Wojdyski, 2016). The starting point for targeting individual ads is personal information, which can provide benefits when combined with behavioral data (Norberg & Horne, 2014). Previous research suggests that ad personalization can elicit both positive and negative consumer responses (Bleier & Eisenbeiss, 2015; Tucker 2012). White et al. (2008) examined the conditions under which personalized promotional emails elicit responses to their personalization approach and argued that messages containing personal information threaten consumers' perceived ability to avoid close monitoring by companies. Tucker (2014) examined personalized banner ads tailored to consumer behavior on a social network and interpreted the reaction somewhat differently than White et al. (2008). While White et al. (2008) intentionally excluded privacy concerns in their laboratory experiment, Tucker (2014) argued that consumers experience reactance due to the perceived invasion of privacy by personalized advertising. In addition, Van Doorn and Hoekstra (2013) used perceived intrusiveness to measure consumers' negative reactions to display banners, which include several different consumer reactions such as reactance and privacy concerns. Keyzer, Dens & De Pelsmacker (2015) demonstrate that when ads on social networks are perceived as more personalized, it boosts responses, primarily because of the perceived relevance of these ads.

The communication privacy management theory (Petronio, 2004) affirms that despite evaluating the risks associated with their actions, individuals are inclined to sacrifice a degree of privacy in exchange for the benefits they gain from using social media (Jacobson, Gruzd & Hernandez-Garcia, 2020). According to Dwivedi et al. (2021) this can be fruitful in future research.

This study aims to explore the relationship of the customer perception of data threat, and their social media and smartphone usage, with the perception of ad transparency.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

According to Awad & Krishnan (2006), consumers are less concerned about having comprehensive awareness of the specifics of data storage, because their primary interest lies in being assured that the company has a well-defined privacy policy. However, personalized advertisement can increase click-through intent when customers are aware of a company's data collection (Aguirre et al., 2015). Consumers' limited awareness of the data collection methods employed by marketers frequently leads to privacy concerns (Kim, Barasz & John, 2019). Over the past few years, this issue has gained greater public recognition, leading to increased awareness of privacy infringements (Treiblmaier & Pollach, 2007). Karwatzki et al. (2017) indicate that consumers desire more information about how companies collect and utilize their data. On the other hand, users make decisions about sharing their data by weighing the benefits (such as discounts and convenience) against the potential costs (such as security risks and identity theft) (Wang et al., 2015; Wilson & Valacich, 2012). The privacy calculus model suggests that users are more willing to share data when the expected benefits outweigh the costs (Dinev & Hart, 2006). However, users may still express concerns about data loss, creating a gap between their expressed attitudes and their actual behavior (Trepte et al., 2015). According to Barth and de Jong (2017), users are usually guided by weighing the risks and benefits when deciding whether to share their privacy information, with risk judged to be minimal or nonexistent. Therefore, it is assumed that customer awareness of data collection practices significantly contributes to perceived ad transparency. Accordingly, the following hypothesis is defined:

H1: Perception of data threat is positively related to ad transparency perception.

Personalized digital marketing offers benefits such as time, labor, and cost savings by providing the most relevant products, information, and offers through consumers' preferred communication channels (Aksoy et al., 2021). However, digital personalization can also lead to increased irritation and intrusiveness, which raises privacy concerns and may lead consumers to either avoid certain digital technologies altogether or limit technologies that enable the delivery of personalized content (Baek & Morimoto, 2012; Strycharz et al., 2019; Brinson et al., 2018). The use of digital communication technologies such as smartphones for various purposes during the day has become mainstream in the last decade (Vitezić & Perić, 2021; Elahi et al., 2019). The frequent use of smartphones leads to a habit (Venkatesh et al., 2012) and an

accumulation of experience, knowledge and confidence, which could reduce the perceived effort and anxiety of AI use (Gursoy et al., 2019). Engagement in social networking sites (SNSs) is a key online social characteristic of respondents, as the act of sharing experiences is inherently a social endeavor (Munzel & Kunz, 2014; Cloarec, Meyer-Waarden & Munzel, 2021).

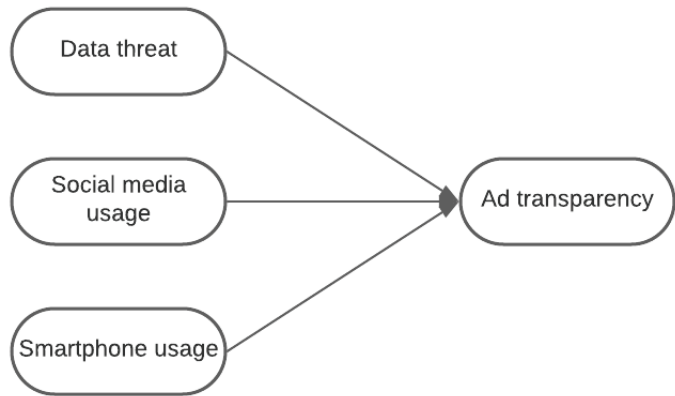
Prior research has indicated that advertising personalization can have both positive and negative effects. The positive effects are visible through self-referencing (De Keyzer, Dens & De Pelsmacker, 2015; Walrave et al., 2016), while generating negative thoughts in general (Maslowska et al., 2016). Negative effects are considered through perceived intrusiveness (De Keyzer, Dens, & De Pelsmacker, 2018; van Doorn & Hoekstra, 2013). On the other hand, consumers exhibit a higher level of attention toward personalized advertisements in contrast to generic ones (Wojdyski & Bang, 2016), but both trust and anticipated benefits associated with personalization decrease (Bol et al., 2018). However, negative effects may offset each other, where there are no significant differences between ads personalized with first names/photos and non-personalized ads in terms of attitudes toward the ad and intentions to pursue job opportunities (Pfiffelmann and Soulez, 2018). Not all consumers may feel comfortable with social media listening, which has proven to be a valuable tool for businesses to gain data (Jacobson, Gruzd & Hernandez-Garcia, 2020; Lee, 2018). If consumers are uncomfortable with how marketers use social media data, it can lead to negative attitudes, potentially impacting their intention to make purchases and causing damage to the consumer-company relationship (Goldfarb and Tucker, 2013). However, the situation changes when it comes to publicly shared user-generated content on social media. The majority of social media platforms promote the use of data for marketing purposes, facilitating it through well-established Application Programming Interfaces. On social media, people willingly and consciously share their thoughts, feelings, and life experiences with others (Posey et al., 2010). Online self-disclosure refers to the act of individuals sharing their confidential details or personal preferences with others through online platforms, either for economic gain or to seek social support (Shih, Lai & Cheng, 2017). According to Zeng et al. (2021), explaining the combination of privacy and personalization may lead customers to intensify their self-disclosure. Therefore, the following hypotheses are formulated as follows:

H2: Frequency of social media usage is positively related to ad transparency perception.

H3: Frequency of smartphone usage is positively related to ad transparency perception.

Based on the hypotheses developed above, the conceptual model of the study is shown in Figure 1.

Figure 1. Conceptual model of the study



Source: The author

METHODOLOGY

In order to test the formulated hypotheses, an empirical study was conducted using survey methodology. A self-administered structured questionnaire was used as the measuring instrument, based on the relevant literature, with questions tailored to the requirements of this study. The questionnaire is divided into four groups and follows the funnel principle. Using a five-point Likert scale, anchored at 1 = strongly disagree and 5 = strongly agree, participants rated their level of agreement with the questionnaire items. Statements by Vitezić and Perić (2021) were used to measure the smartphone usage. Perception of data threat was assessed using statements by Brinson et al. (2020), while the ad transparency construct was adapted from Karwatzki et al. (2017) and Jovanovska (2021).

The survey was conducted from March to June 2022 by means of an online survey distributed via email and social media. The sample was drawn using the simple random sampling method. The questionnaires were randomly distributed across different platforms to capture a wide range of perspectives. At the beginning of the questionnaire, all participants were informed about the topic and the objectives of the study. A control question was formulated to check whether the respondents had at least one active social media account,

so the research sample consists of consumers with experience participating in online social networks (Aguirre et al., 2015; Jacobson, Gruzd & Hernandez-Garcia, 2020). After correcting for inaccuracies and missing data, a total of 497 correctly completed questionnaires were deemed suitable for subsequent analysis.

Evaluations of the outer model, inner model, and hypothesis testing were conducted with SmartPLS 4 using the Partial Least Squares Structural Equation Modelling (PLS-SEM) approach, which is preferred for studies focusing on prediction and theory development (Henseler et al., 2016).

Among the 497 valid questionnaires, 70.49% of respondents were female and 29.51% were male. The majority of the respondents were younger, with 58.4% between 25 and 30 years of age and 22.9% between 18 and 24. Fewer respondents belonged to the “31-40” (12.1%), “41-50” (3.8%), and “over 51” (10.6%) age groups. Although predominantly young, the respondent structure corresponds to the selected data collection media. In terms of education, most respondents had a bachelor’s degree (40.31%) and a master’s degree (19.5%), followed by those with a high school diploma (38.6%). Correspondingly, they were predominantly students (52.4%) and full-time employees (36.83%), while 4.41% were unemployed. In response to the question of how many ads (paid messages where the brand is known) they have seen on social networks in the last two weeks, the respondents provided the following answers: 1-5 (8.08%), 6-10 (12.79%), 11-20 (15.81%), 21-30 (11.62%), more than 30 (18.76%), can’t count (30.72%).

RESULTS

A two-step analytical approach was used to examine the three hypotheses. In the first step, internal consistency, reliability, and convergent validity of the measurement scales were assessed. Secondly, the research model was evaluated by testing the hypotheses, estimating path coefficients, determining the variance explained, and assessing statistical significance.

MEASUREMENT MODEL RESULTS

This model was evaluated using an analysis of convergent validity (including factor loadings and average variance extracted - AVE), internal consistency (measured by Cronbach’s alpha and composite reliability), and discriminant

validity (Heterotrait-Monotrait ratio - HTMT), with the values presented in Table 1.

Table 1: Outer model evaluation

Code of constructs/ variables	Outer loadings	Cronbach's Alpha	Composite Reliability	AVE
Data threat		0.852	0.857	0.772
DATA1	0.873			
DATA2	0.902			
DATA3	0.859			
Smartphone usage		0.896	0.922	0.704
SMART1	0.823			
SMART2	0.877			
SMART3	0.759			
SMART4	0.848			
SMART5	0.882			
Social media usage		0.710	0.743	0.531
SOC1	0.838			
SOC2	0.679			
SOC3	0.671			
SOC4	0.714			
Ad transparency		0.913	0.925	0.694
AD1	0.844			
AD2	0.846			
AD3	0.871			
AD4	0.856			
AD5	0.817			
AD6	0.760			

Source: The author

The values obtained in the outer model evaluation indicate satisfactory levels for all metric attributes. Manifest variables have outer factor loadings ranging from 0.671 to 0.902, and were all included in the further analysis (Hair et al., 2017). The indicator variables with outer loadings ranging from 0.6 to 0.7 were retained because composite reliability values and Cronbach's alpha coefficient were above the recommended level of 0.7, while the average variance extracted of indicators was above 0.5, therefore the elimination of two variables in the Social media usage construct would not bring a considerable increase in the values of the mentioned coefficients (Nunally and Bernstein,

1994, Hair et al. 2013). With both Cronbach’s alpha and CR coefficients surpassing 0.7, internal consistency across all factors is deemed satisfactory (Nunnally & Bernstein, 1994). The average variance extracted (AVE) surpasses the minimum threshold of 0.5, indicating that, on average, constructs explain more than half of the variance of their respective indicators (Malhotra, 2010).

The discriminant validity was assessed using the Heterotrait-Monotrait ratio (HTMT), presented in Table 2.

Table 2: Heterotrait-Monotrait ratio

	Ad Transparency	Data threat	Social media usage
Data threat	0.709		
Social media usage	0.274	0.137	
Smartphone usage	0.355	0.357	0.609

Source: The author

The Heterotrait-Monotrait ratio (HTMT) ranges from 0.274 to 0.6709, which is below the recommended threshold of 0.9. Therefore, the measurement model achieved discriminant validity. Table 3 presents the results of the variance inflation factors (VIF).

Table 3: Variance inflation factor inner model matrix

	Ad Transparency
Data threat	1.129
Social media usage	1.340
Smartphone usage	1.487

Source: The author

Variance inflation factors (VIF), with all values below 5, indicate that no multicollinearity can be detected.

HYPOTHESES TESTING

The bootstrapping procedure with a sample of 5000 subsamples was applied to test the hypotheses. By observing the coefficient of determination (R^2), the endogenous variable Ad transparency is moderately explained by the exogenous variables Data threat, Social media usage and Smartphone usage for 44.4%. The PLSpredict was conducted to test the predictive relevance (Q^2 pre-

dict) of the research model. The Q² value is greater than zero, and for Ad transparency amounts to 0.432. That means that the exogenous variables are good enough to predict the endogenous variable, and the predictive relevance of the model is acceptable (Hair et al., 2017).

Table 4 presents the estimated path coefficients, standard deviations, t-values, p-values and confident intervals of the research model.

Table 4: Structural model assessment

	β	STDEV	t- statistics	p-value	Confidence interval 95%	Supported
H1 Data threat → Ad transparency	0.605	0.044	13.876	0.000	0.516- 0.688	✓
H2 Social media usage → Ad transparency	0.119	0.038	3.154	0.002	0.051- 0.199	✓
H3 Smartphone usage → Ad transparency	0.078	0.045	1.706	0.088	-0.012- 0.168	X

Source: The author

The results of the structural model show that the constructs Data threat ($\beta=0.605$; $p<0.05$), and Social media usage ($\beta=0.119$; $p<0.05$), have a significant and positive effect on Ad transparency perception. Therefore, H1 and H2 are supported. The construct Smartphone usage ($\beta=0.078$; $p>0.05$), has a non-significant and positive relationship with Ad transparency perception.

DISCUSSION AND CONCLUSION

This study examined the relationships between the perceptions of data threat, social media usage, and smartphone engagement in relation to consumers’ perceptions of advertising transparency. This study advances the understanding of how perceptions of data threat and social media usage influence ad transparency, and emphasizes the importance of privacy-conscious practices in the digital advertising landscape. By addressing consumer privacy concerns

and promoting transparency, companies can not only increase consumer trust, but can also achieve greater efficiency in personalized advertising strategies. As digital engagement continues to evolve, the principles of transparency, ethical data use and consumer empowerment will play a central role in building sustainable and trustworthy relationships between brands and their target audiences. The study emphasizes the role of data threat as an important precondition for advertising transparency. This aligns with the previous studies emphasizing consumers' heightened sensitivity to privacy issues (Aguirre et al., 2015; Barth & de Jong, 2017) and supports the privacy calculus model, which states that consumers weigh the perceived risks and benefits before disclosing personal information (Dinev & Hart, 2006). In addition, social media use was found to be a significant determinant of ad transparency, supporting the idea that platforms that enable higher user engagement promote greater awareness and informed attitudes towards data practices (Jacobson, Gruzd & Hernandez-Garcia, 2020; Keyzer, Dens & De Pelsmacker, 2015). The fact that there is no significant correlation between smartphone use and the perception of advertising transparency emphasizes the differentiated role of different digital devices in shaping consumer attitudes. While smartphones are an essential component of digital engagement, their ubiquity can lead to habitual rather than reflective interactions, as Venkatesh et al. (2012) argue.

This study contributes to the personalization-privacy paradox by showing that, while personalized advertising increases perceived relevance, it also raises privacy concerns. This duality mirrors the findings of Awad & Krishnan (2006) and emphasizes the importance of transparent data practices to mitigate negative consumer reactions. Furthermore, the findings emphasize the role of communication privacy management theory (Petronio, 2002), which shows that consumers' willingness to disclose personal information is moderated by their evaluation of the risks and benefits associated with such disclosure.

For marketers, these findings emphasize the critical importance of clear and transparent communication about data collection and usage practices. Companies should prioritize the development of privacy policies and ensure that these are visible to consumers, as this promotes trust and improves the perception of transparency. Social media platforms should utilize user engagement to promote transparency initiatives in order to meet the growing consumer expectations for ethical data handling. By offering tools to customize and control privacy settings, platforms can empower users to allay their privacy concerns, ultimately fostering trust and loyalty.

The study's findings are particularly relevant for advertisers looking to resolve the personalization-privacy paradox. Strategies that strike a balance

between personalization and transparency, such as opt-in mechanisms for targeted advertising and simplified privacy settings, can mitigate privacy concerns while maintaining the perceived relevance of advertising. Furthermore, the findings suggest that the gap between consumers' expressed concerns and their actual behavior can be bridged if consumers are better educated about data practices, and if greater user ownership is encouraged through participatory initiatives.

Despite its contribution, this study is not without limitations. The use of self-reported data may lead to response bias, and the cross-sectional nature of the study limits causal conclusions. Future research should consider longitudinal studies in order to examine how consumer attitudes and behaviors change over time. In addition, increasing the demographic diversity of the sample would improve the generalizability of the results. Examining the cultural differences in terms of privacy and perceptions of advertising transparency could provide valuable insights for global marketing strategies.

Further studies should also investigate the role of additional variables, such as perceived ease of use, social influence or trust in the platform, so as to increase the explanatory power of the model. Mixed-methods approaches that combine quantitative analyses with qualitative findings would enrich the understanding of consumer attitudes and behaviors. Finally, comparative studies across different social media platforms and device types could shed light on platform-specific dynamics and offer customized recommendations for marketers.

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ANALYSIS OF SDGS REPORTING OF CROATIAN LISTED COMPANIES – EVIDENCE FROM NONFINANCIAL STATEMENTS

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After their introduction by the United Nations in 2015, Sustainable Development Goals (SDGs) have become a focus of interest for practitioners and scientists from different fields. The defined SDGs can only be achieved through the collaboration of a broad group of societal stakeholders, companies being one of them. Companies can significantly contribute to achieving those goals, so they need to consider them while defining their strategy and conducting business operations. While carrying out activities that contribute to achieving the SDGs, it is also important to communicate such activities and results to a broader group of stakeholders. One important tool for disclosing such information is the nonfinancial statement, i.e. a statement in which companies present information related to environmental, social, and governance (ESG) issues. As evident, the content of nonfinancial statements overlaps with the coverage of the SDGs, which can also be linked with ESG issues.

Considering the importance of reporting on the SDGs, the objective of this research is to analyze whether Croatian public listed companies have recognized the importance of SDGs reporting and, if so, which SDGs have been most/least identified by these companies. The starting point for the research was to determine which Croatian public listed companies were obligated to prepare nonfinancial statements (large public-interest companies with more than 500 employees) for 2023. This analysis revealed that 29 companies met those criteria. During the analysis, three companies were excluded because they were exempt from the obligation to

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prepare a nonfinancial statement (the nonfinancial statement is prepared at the level of the parent company), resulting in a final sample of 26 companies. Those companies' nonfinancial statements were subject to content analysis in order to reveal whether the SDGs have been addressed and, if yes, which ones. The results revealed that most companies (18 out of 26, or 69%) included SDGs in their nonfinancial statements. The analysis also showed differences in the number of SDGs covered by the companies and the amount of information provided for each SDG. Some companies focused on a smaller number of SDGs and provided detailed information on how they contribute to achieving them, while others reported a higher number of SDGs (or all 17) without giving specific details. The most commonly covered goal is SDG 12: Responsible consumption and production (reported by 17 out of 26 companies, or 65%), followed by SDG 4: Quality education, SDG 7: Affordable and clean energy, and SDG 13: Climate action (each reported by 16 out of 26 companies, or 62%), as well as SDG 3: Good health and well-being and SDG 8: Decent work and economic growth (each reported by 15 out of 26 companies, or 58%). The high representation of these SDGs is in line with the characteristics of the modern business environment in which consumer issues, climate issues, and education are frequently referenced. On the other hand, SDG 2: Zero hunger was reported by only 3 companies (12%), while SDG 1: No poverty and SDG 14: Life below water were reported by just 6 companies (23%). At the country level, Croatia has achieved SDG 1: No poverty, therefore no additional actions are required, while for the other least represented SDGs (significant) challenges remain, and companies should make extra efforts to achieve them and report on them.

Based on the conducted analysis, it can be concluded that Croatian public listed companies have recognized the importance of SDGs reporting and their role in achieving the goals. However, the analysis has also revealed significant differences in the amount of information disclosed, suggesting that the standardization and harmonization of reporting on contributions to achieving the SDGs should be further developed. Having standardized and harmonized information would allow for better comparisons across different periods and between companies. In such a way, progress that has been made could be analyzed. Following the obtained conclusions, recommendations for further development of SDGs reporting in nonfinancial statements are made, primarily referring to the expansion of companies obligated to prepare nonfinancial statements, mandatory implementation of the European Sustainability Reporting Standards

(ESRS) and development of the SDG index at the company level. The obtained results were compared with similar research analyses from other countries.

Keywords: *SDGs, sustainable development, nonfinancial reporting, Croatia*

JEL classification: *Q01, M14, M41*

INTRODUCTION

The Sustainable Development Goals (SDGs) were presented by the United Nations in 2015 with the aim to make the world a better place by 2030 (UN, 2015). They include goals and concrete sub-goals that should be achieved. SDGs refer to environmental, social, and governance (ESG) issues. All members of the society, such as governments, companies, NGOs, citizens, etc. should strive to contribute to their achievement. Collaboration among society members is crucial to making the world a better place.

As stated earlier, companies can contribute significantly to achieving the SDGs by incorporating relevant activities into their strategies and daily operations. Additionally, these organizations should effectively communicate the actions and results achieved regarding the SDGs. One tool that a company can use for such communication are nonfinancial statements, often named sustainability reports. Nonfinancial reporting includes disclosure of information related to environmental, social, and governance (ESG) issues. Notably, there is an overlap between nonfinancial reporting and SDGs, as both cover ESG issues. The inclusion of SDGs in nonfinancial reports has seen rapid growth in the years after they were introduced (KPMG, 2024).

Nonfinancial reporting is also mandatory for certain companies operating in European Union member countries, in line with the Non-Financial Reporting Directive (NFRD) introduced in 2014. With the introduction of the new Corporate Sustainability Reporting Directive (CSRD Directive) in 2022, in force as of 2025, the number of companies obligated to prepare nonfinancial statements will increase. Given the overlap in the topics covered, it is also expected that SDGs reporting will expand.

In this research, the focus was on Croatian public listed companies which, in line with the NFRD Directive, were obligated to prepare a nonfinancial statement for the year 2023 (the last available year). The nonfinancial statements of Croatian public listed companies have been analyzed with the aim of

collecting information on whether companies have recognized the importance of SDGs by addressing them in their nonfinancial statements and, if yes, which SDGs have been the most/least addressed by the considered companies.

Through the results obtained and discussed, this paper contributes to the literature on SDGs and nonfinancial reporting by showing that Croatian public listed companies have recognized their role in achieving global SDGs by addressing them in their nonfinancial statements. Based on the identification of most/least represented SDGs, conclusions about the further development of SDGs reporting were made. An additional contribution of this research is in emphasizing the need for standardization and harmonization of nonfinancial reporting, which is expected to have a positive effect on SDGs reporting as well. This paper also confirms the need for implementing and further developing the reporting frameworks and standards for nonfinancial reporting, including SDGs reporting like ESRS standards.

This paper includes five sections. After the introduction, a literature review regarding the sustainable development goals (SDGs), nonfinancial reporting, and reporting on SDGs in nonfinancial statements is presented. The third section includes a description of the methodology used in this analysis, while the fourth section presents and discusses the results. The paper closes with a conclusion on the topic.

LITERATURE REVIEW

IMPORTANCE OF SDGS FOR BUSINESS

Sustainable Development Goals (SDGs) represent “a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity” (UN, 2015). Since their introduction in 2015, SDGs have become the focus of researchers from various fields, as they refer to environmental, economic, and social issues. As Cordova and Celone (2019, p.1) stated, “the implementation of the agenda requires a strong involvement of all members of society, especially business”. Table 1 presents the list of SDGs defined by the United Nations in 2015. There are 17 goals, and each goal also contains concrete sub-goals which should be achieved by 2030.

Table 1: Sustainable Development Goals (SDGs)

Sustainable development goal	Goal title and description
SDG 1	No poverty: “End poverty in all its forms, everywhere”
SDG 2	Zero hunger: “End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.”
SDG 3	Good health and well-being: “Ensure healthy lives and promote well-being for all, at all ages.”
SDG 4	Quality education: “Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.”
SDG 5	Gender equality: “Achieve gender equality and empower all women and girls.”
SDG 6	Clean water and sanitation: “Ensure availability and sustainable management of water and sanitation for all.”
SDG 7	Affordable and clean energy: “Ensure access to affordable, reliable, sustainable and modern energy for all.”
SDG 8	Decent work and economic growth: “Promote inclusive and sustainable economic growth, full and productive employment, and decent work for all.”
SDG 9	Industry, innovation and infrastructure: “Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.”
SDG 10	Reduced inequalities: “Reduce inequality within and among countries.”
SDG 11	Sustainable cities and communities: “Make cities and human settlements inclusive, safe, resilient and sustainable.”
SDG 12	Responsible consumption and production: “Ensure sustainable consumption and production patterns.”
SDG 13	Climate action: “Take urgent action to combat climate change and its impacts.”
SDG 14	Life below water: “Conserve and sustainably use the oceans, seas and marine resources for sustainable development.”
SDG 15	Life on land: “Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation, and halt biodiversity loss.”
SDG 16	Peace, justice and strong institutions: “Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.”
SDG 17	Partnership for the goals: “Strengthen the means of implementation and revitalize the global partnership for sustainable development.”

Source: United Nations, Department of Economic and Social Affairs - Sustainable Development (2025), available at <https://sdgs.un.org/goals> (23.12.2024.)

In this paper, the focus will be on the economic effects of SDGs. The literature shows that “the interest of companies toward SDGs is growing” (Cordova & Celone, 2019, p.1). According to Scheyvens et al. (2016, p. 371), the business sector has “a strong role in influencing the development of the SDGs mostly through innovation, responsiveness, efficiency and provision of specific skills and resources”. The SDGs also help companies “to have a much clearer set of long-term global priorities with a political tailwind, and the alignment between policymakers, civil society and the private sector is much stronger” (Pedersen, 2018, p. 21).

SDGS AND NONFINANCIAL REPORTING

Undoubtedly, companies have the opportunity to contribute significantly to the achievement of SDGs, so they need to consider them when defining their strategies and conducting business operations. Additionally, it is important to communicate such activities and results to a wider group of stakeholders. One tool that can be used for such communication is nonfinancial statements. Communication on SDGs by companies through nonfinancial statements is the focus of this paper. A nonfinancial statement is described as “a report published by companies on the environmental, social and governance (ESG) impacts of their activities that enable addressees and users to understand more clearly the impacts of a company’s business activities on the environment and society and to assess the risks and opportunities companies face, or which are offered to them” (PWC, n.d.).

In the EU, nonfinancial reporting is also mandatory for certain companies. In line with the provisions of the Nonfinancial Reporting Directive (NFRD) from 2014, large companies with more than 500 employees that are also public interest entities are obligated to prepare and disclose nonfinancial reports containing sustainability information. In 2022, the new Corporate Sustainability Reporting Directive (CSRD Directive) was introduced. Under the CSRD, all large, medium-sized, and small public interest companies will be required to prepare and disclose nonfinancial statements starting from 2025. The CSRD is expected to increase the volume and details of disclosed sustainability information.

In relation to the main topics covered by the definition of nonfinancial statements, SDGs could also be divided into the same three categories (environmental, social, and governance). Table 2 shows SDGs according to the aforementioned three categories. Therefore, it is evident that there is a connection between SDGs and nonfinancial reporting.

Table 3: Sustainable Development Goals groups

Environment	Social	Governance
SDG 6 Clean water and sanitation	SDG 1 No poverty	SDG 5 Gender equality
SDG 7 Affordable and clean energy	SDG 2 Zero hunger	SDG 8 Decent work and economic growth
SDG 9 Industry, innovation and infrastructure	SDG 3 Good health and well-being	SDG 9 Industry, innovation and infrastructure
SDG 11 Sustainable cities and communities	SDG 4 Quality education	SDG 11 Sustainable cities and communities
SDG 12 Responsible consumption and production	SDG 5 Gender equality	SDG 12 Responsible consumption and production
SDG 13 Climate action	SDG 6 Clean water and sanitation	SDG 13 Climate action
SDG 14 Life below water	SDG 8 Decent work and economic growth	SDG 16 Peace, justice and strong institutions
SDG 15 Life on land	SDG 9 Industry, innovation and infrastructure	SDG 17 Partnership for the goals
	SDG 10 Reduced inequalities	
	SDG 12 Responsible consumption and production	
	SDG 16 Peace, justice and strong institutions	

Source: Berenberg (2018): Understanding the SDGs in sustainable investing, available at: https://www.berenberg.de/uploads/web/Asset-Management/ESG/SDG_understanding_SDGs_in_sustainable_investing.pdf (23.12.2024.)

Related to nonfinancial reporting, SDGs reporting can be defined as “the practice of reporting public on how an organization addresses the SDGs” (Rosati & Faria, 2019, p. 1313). Mio et al. (2020) emphasized that businesses increasingly acknowledge the importance of incorporating SDGs into their strategic frameworks, which can improve their sustainability performance and foster greater stakeholder engagement. KPMG’s (2024) study on nonfinancial reporting showed that approx. 75% of the world’s biggest companies are reporting on SDGs. Evidently, corporate reporting on SDGs is on the rise (Bose & Khan, 2022), but it remains primarily concentrated in developed nations (Low et al., 2023) and among large corporations (Datta & Goyal, 2022). Similarly, a study conducted by Fonseca, L. and Carvalho (2019) suggests that organizations are more likely to prominently communicate SDGs if they have a high business volume, if they are members of the UN Global Compact Network, and if they publish their nonfinancial reports on their websites. Rosati and Faria (2019, p. 1312) have also analyzed the characteristics of companies reporting on SDGs, and found that companies “located in countries with higher levels of climate change vulnerability, national corporate social responsibility, company

spending on tertiary education, indulgence and individualism, and lower levels of market coordination, employment protection, power distance and long-term orientation” are more prone to report on SDGs. Considering nonfinancial reporting based on SDGs in Central and Eastern European countries, Nechita et al. (2020) concluded that companies are contributing to the achievement of SDGs, especially the ones related to the environment and decent work of employees.

As for the content of nonfinancial reporting related to SDGs, Urbieta (2024) identified the following six issues/aspects that are frequently reported: (1) SDG-related materiality analysis, (2) Integration of the SDGs in the formulation of corporate objectives, (3) Identification of potential risks and opportunities related to each SDG, (4) Disclosure of investments made for SDG-related projects, (5) SDG-related measures and (6) SDG-related best practices. Costa et al. (2022) concluded that while companies mention SDGs in their reports, they fail to clearly state how key sustainability initiatives influence their contributions to the SDGs achievement. The authors also emphasize the need for a practical framework to help companies enhance transparency in nonfinancial reporting and accurately reflect their contributions to Agenda 2030.

Based on the presented literature review, it can be concluded that companies have an important role in achieving SDGs. The literature review also shows that companies are reporting on SDGs, meaning they have recognized the importance of communicating, and their contribution to achieving SDGs. In view of all the aforementioned, the following research question is defined:

RQ1: Have Croatian public listed companies recognized the importance of SDGs reporting in nonfinancial reports?

Additionally, literature shows companies are reporting different information related to SDGs, so the following research question is also defined:

RQ2: Which SDGs are most/least reported by Croatian public listed companies?

METHODOLOGY

The research questions were tested using a sample of public listed Croatian companies. Of all the listed companies in November 2024, 29 companies were obligated to prepare a nonfinancial statement for the year 2023 (public interest companies with more than 500 employees). During the analysis, three companies were excluded since they were exempt from the obligation to prepare a nonfinancial statement (the nonfinancial statement is prepared at the level

of the parent company). Considering all the abovementioned factors, the final sample was comprised of 26 companies. Table 2 contains information about the companies included in the sample by activity sector. The majority of included companies are from the manufacturing sector, which is not surprising since this is one of the largest sectors in Croatia (1st according to the number of employees, 2nd according to total revenues, and 4th according to the number of companies in 2023) (FINA, 2024). Sectors significantly consumer-oriented are Sector I and Sector K.

Table 2: Companies by activity sector

Activity sector	Number of companies
A- Agriculture, forestry and fishing	1
C- Manufacturing	8
E- Water supply; sewerage, waste management and remediation activities	1
G - Wholesale and retail trade; repair of motor vehicles and motorcycles	2
H - Transportation and storage	2
I - Accommodation and food service activities	4
J - Information and communication	3
K - Financial and insurance activities	4
M - Professional, scientific and technical activities	1
Total	26

Source: Author’s calculation based on InfoBiz.hr

By focusing only on companies obligated to prepare nonfinancial statements, the sample was limited only to the largest companies, which has been confirmed by the data in Table 3 (number of employees, total assets, and total revenues). On average, the included companies have been operating profitably (only two companies from the sample reported negative business results). Included companies are also active in investments, and the average value of investments is EUR 38 mil. The average net salary of the companies considered is above the national average (EUR 1,148 for 2023 in private companies (DZS, 2024)).

Table 3: Selected financial data of the companies included in the sample (the year 2023)

	Number of employees	Total revenues (mil €)	Profit/ Loss (mil €)	Total asset (mil €)	Investments (mil €)	Average net salary
N	26	26	26	26	22	24
Mean	1,618	642.06	51.69	2,017.88	38.09	1,558.88
Median	873	218.90	9.61	308.00	5.44	1,580.50
Min	510	34.08	- 12.59	52.98	-	838.00
Max	4,845	6,459.96	450.36	20,373.24	324.57	2,329.00

Source: Author's calculation based on InfoBiz.hr

In order to provide answers to the defined research question, a content analysis of companies' nonfinancial statements was conducted. The companies included their nonfinancial statements in the annual (integrated) statements or prepared separate nonfinancial statements. The statements were collected from the Zagreb Stock Exchange web page and/or companies' web pages. The content analysis was conducted manually by screening the entire report for keywords (such as Croatian translation of terms SDG and sustainable development goals) and by analyzing the graphics (figures and tables). The companies reported on SDGs in different locations in the report, mostly as a sub-section.

RESEARCH RESULTS AND DISCUSSION

The main results of the conducted content analysis are presented in Table 4 and Figure 1. As seen from the table and the figure, the majority of included companies (18 out of 26) have recognized the importance of SDGs reporting in nonfinancial statements. The most commonly referenced goal is SDG 12: Responsible consumption and production, reported by 17 companies (65%). Interestingly, this SDG is one of the goals for which the lowest progress in achievement is reported on the national level (major challenges remain). In the second place of most commonly reported goals are SDG 4: Quality education, SDG 7: Affordable and clean energy and SDG 13: Climate action, each reported by 16 companies (62%). Among others, the second place is occupied by SDG 13 for which the lowest progress in achievement has been reported on the national level as well. From this, it can be concluded that Croatian public interest companies have recognized the SDGs with the lowest achievement and they are dealing with them.

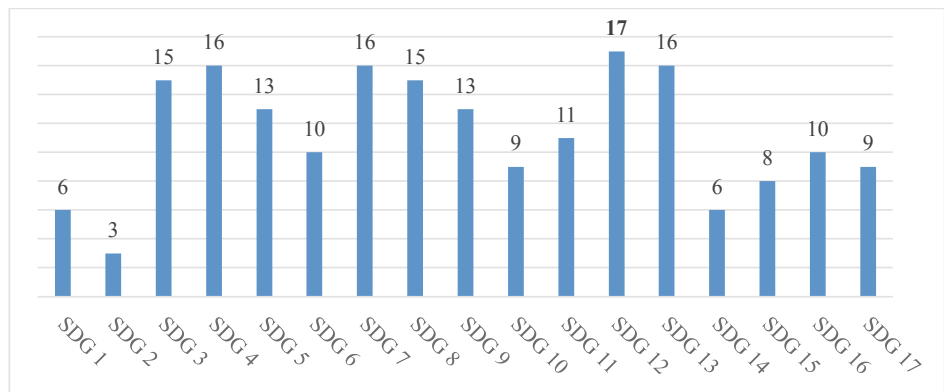
From the table and figure below, it can also be observed which SDGs are least reported by Croatian public listed companies. SDG 2: Zero hunger is reported by only 3 companies (12%), while SDG 1: No poverty and SDG 14: Life below water are reported by only 6 companies (23%). On the national level, Croatia has achieved SDG 1: No poverty, therefore no additional actions are required. For SDG 14, challenges remain on the national level, but moderate improvement is reported. Companies should, therefore, take more account of this SDG, especially since Croatia is very rich in water, and the accommodation and food service activities sector (mostly coast-based with significant direct/indirect effect on water) is among the largest sectors in Croatia. For SDG 2, significant challenges remain on the national level, but moderate improvement is reported. Regarding the achievement of this SDG, companies can be indirectly affected mostly by providing employment opportunities and fair wages. Therefore, there is material for reporting as well.

Table 4: Number of companies reporting on SDGs

	Number of reporting companies	% of reporting companies
Reporting on SDGs *	18	69.23
SDG 1 - No poverty	6	23.08
SDG 2 - Zero hunger	3	11.54
SDG 3 - Good health and well-being	15	57.69
SDG 4 - Quality education	16	61.54
SDG 5 - Gender equality	13	50.00
SDG 6 - Clean water and sanitation	10	38.46
SDG 7 - Affordable and clean energy	16	61.54
SDG 8 - Decent work and economic growth	15	57.69
SDG 9 - Industry, innovation and infrastructure	13	50.00
SDG 10 - Reduced inequalities	9	34.62
SDG 11 - Sustainable cities and communities	11	42.31
SDG 12 - Responsible consumption and production	17	65.38
SDG 13 - Climate action	16	61.54
SDG 14 - Life below water	6	23.08
SDG 15 - Life on land	8	30.77
SDG 16 - Peace, justice and strong institutions	10	38.46
SDG 17 - Partnership for the goals	9	34.62
Number of companies in the sample = 26 * reporting at least 1 SDG		

Source: Author's calculation

Figure 1: Number of companies reporting on SDGs



Source: Author's calculation

The results were also analyzed at the company level. As previously mentioned, 18 companies are reporting on SDGs, meaning that 8 of them are not and have not recognized the importance of SDGs reporting in nonfinancial statements. The analysis has shown differences in the number of reported SDGs, as presented in Table 5 below. On average, companies report 7.42 SDGs in the nonfinancial statements, with a median value of 7.5. The standard deviation is 5.9, and the kurtosis is negative, -1.38. The analysis also revealed that some companies are reporting on a lower number of SDGs, but are providing detailed information about their importance for the company, about the activities taken or results achieved. On the other hand, some companies are addressing a higher number of SDGs (or all 17), but without providing details about their importance, activities conducted, and results obtained. From this, it can be concluded that there is a need for standardization and harmonization in SDGs reporting. Having standardized and harmonized reporting would allow for making quality comparisons between companies and within a company during different years.

Table 5: Number of SDGs reported by companies

	Min	Max	Average	Median	Standard deviation	Kurtosis
Number of reported SDGs per company	0	17	7.42	7.5	5.9	-1.38

Source: Author's calculation

CONCLUSIONS

The global importance of SDGs is undeniable. Companies have also recognized their importance and the role they have in achieving the defined goals. Along with defining corporate strategies, goals, and activities in line with SDGs, it is important to disclose on SDGs to interested parties. In doing so, nonfinancial statements can be an important tool when it comes to reaching those interested. For certain companies, mainly the largest ones and those more publicly exposed, this reporting is mandatory by the law. The regulations are getting stricter and more demanding, which will result in a growing amount of disclosed information in the upcoming years. Considering that nonfinancial statements are the tool for SDGs reporting, it is reasonable to expect that SDGs reporting will increase as well.

In view of the importance of SDGs and communication about them in nonfinancial statements, the aim of this paper was to analyze whether Croatian publicly listed companies have recognized the importance of SDGs reporting and, if yes, which SDGs are most/least addressed by the companies in their nonfinancial statements.

In order to answer the defined research questions, a content analysis of the mandatory nonfinancial statements issued by Croatian public listed companies for 2023 was conducted. The research sample comprised 26 Croatian public listed companies. The obtained results should be discussed taking into account the national progress in achieving SDGs as well. According to the Sustainable Development Goal (SDG) Index Rank, in 2024, Croatia was ranked at the 8th place (out of 166 countries), with an SDG Index Score of 82.19 (max 100) (Sustainable Development Report, 2024). It can be concluded from these data that Croatia as a whole is doing well in terms of achieving the SDGs, but some significant challenges need to be resolved in relation to SDG 12: Responsible consumption and production and SDG 13: Climate action, including the (significant) challenges related to other 13 SDGs. According to the cited report, Croatia has achieved SDG 1: No poverty and SDG 4: Quality education.

The research has confirmed that companies have an important role in achieving the SDGs. Croatian public listed companies have acknowledged the significance of SDGs and their reporting, since the majority of considered organizations have referenced SDGs in their nonfinancial statements. The most cited and least cited SDGs have been identified in this research. The most frequently referenced SDGs include SDG 12: Responsible consumption and production, SDG 4: Quality education, SDG 7: Affordable and clean energy, and SDG 13: Climate action. The least referenced SDGs include SDG 2: Zero

hunger, SDG 1: No poverty and SDG 14: Life below water. Among the most frequently addressed SDGs are also the ones on which Croatia needs to put the most focus, since there are major challenges left in relation to them. Among the least reported SDGs are also those which Croatia has achieved. Therefore, it can be concluded that companies are aware of the challenges left in fulfilling the SDGs.

The results of this research align with the conclusion of Curto-Pages et al. (2021) about the increasing reporting on the SDGs. They have found that SDG 13: Climate action and SDG 4: Quality education are among the most commonly mentioned goals in Spanish-listed companies, while they documented the same least reported goals (SDG 1: No poverty, SDG 14: Life below water and SDG 2: Zero hunger) as was the case in this analysis. A partial overlap in the most/least referenced SDGs exists in the results reported for Italian companies. Izzo et al. (2020) found that SDG 8: Decent work and economic growth, SDG 13: Climate action and SDG 9: Industry, innovation and infrastructure are the most commonly represented, while SDG 2: Zero hunger, SDG 14: Life below water, and SDG 15: Life on land are the ones least mentioned in reports.

Although Croatian public listed companies have identified the importance of reporting on SDGs in nonfinancial reports, the research has revealed certain weak points, mostly related to the low levels of standardization and harmonization of published information. The number of covered SDGs and the amount of information per covered SDG deviates among companies. Some companies are referencing all SDGs (or almost all) without going into details, while other companies are focusing only on the most important ones, but providing detailed information. In order to compare the results among companies, but also within companies, standardized reports would be helpful. Mandatory nonfinancial statements by companies in the EU that will be published in 2025 will need to be prepared using the ESRS (European Sustainability Reporting Standards), which is expected to positively affect the level of standardization and harmonization of this reporting. The SDGs are the foundation of the EU sustainability policies that, among others, also include European Sustainability Reporting Standards (ESRS) (Bajica & Pavlović, 2024).

The paper contributes to the literature on SDGs reporting and nonfinancial reporting by confirming the importance of companies in achieving SDGs. Using a sample of Croatian public listed companies, it has been shown that SDGs reporting is part of the nonfinancial statements of most considered companies, and the most/least mentioned SDGs have been revealed. An additional contribution is in emphasizing the need for standardization and harmonization of nonfinancial reporting.

Considering the ESRS standards, future research should focus on report standardization, which would contribute to reporting quality. Additionally, it would be useful to have an index to measure the achievement of SDGs by company, just as it is at the country level. There was an attempt to develop such an index, called the Sustainable Development Goals Business Index (SDGBI), which should have been “the world’s first Index ranked based on the review of SDGs-based” (UN, Department of Economic and Social Affairs, n.d.). However, this index did not go ahead as planned. Such an index would also have a positive effect on SDGs reporting standardization. The content of disclosed information should also be the focus of further research.

The main limitation of this paper is in the sample size, coverage of only public listed companies, and focus on just one country. These limitations result from focusing only on companies obligated to prepare nonfinancial statements in a small country. Expanding the number of companies obligated to prepare nonfinancial statements in the future (the result of the CSRD Directive) would allow for the use of larger samples and statements with more standardized information. Furthermore, in future research, companies from different countries should be included, which would lead to conclusions about the country’s effect.

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FROM INNOVATIVE LEADERS TO INNOVATIVE EMPLOYEES: THE MEDIATING ROLE OF JOB DESIGN AND WORK ENGAGEMENT

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Nowadays, employees face increasing demands for flexibility and innovation, therefore leaders who foster creativity, collaboration, and resilience are essential for driving innovation and ideas. Extensive research has explored leadership, employee engagement, and innovative work behavior (IWB), however, the specific link between innovative leadership and these factors remains underexplored. This study aims to examine the relationship between innovative leadership and IWB, with the mediating role of job resources, job demands and work engagement within Croatian IT organizations. By enhancing the reliability of the innovative leadership scale and validating this relatively new measure, we seek to support its use in future research on the influence of leadership on engagement and innovation. The primary data was collected by means of a structured online questionnaire administered to a sample of 101 employees in the leading IT companies. For construct measurement, validated Likert-type scales were used. The conducted path analysis indicates a direct relationship between innovative leadership and work engagement, as well as an indirect relationship through job demands and resources. A significant positive relationship between innovative leadership and job resources was found, suggesting that innovative leaders facilitate access to valuable resources such as autonomy, social support, and performance feedback.

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Additionally, it has a negative influence on job demands, including work pressure, emotional, physical, and mental stressors. Both job resources and job demands are positively related to work engagement and, at the same time, positively linked to IWB. These findings emphasized the potential for innovative leadership to effectively manage job design, leveraging both demands and resources to foster a workplace that promotes engagement and IWB. A contribution to the emerging literature on innovative leadership is made by the empirical validation of its impact within the JD-R framework. This study thus provides valuable insights for leaders to adopt innovative leadership behavior, and emphasizes its importance in terms of facilitating an engaged and innovative workforce. Considering that innovative leadership enhances IWB, fostering a balance between job demands and job resources through innovative leadership may positively impact employee well-being.

Keywords: *innovative leadership, job design, job demands-resources (JD-R) model, work engagement, innovative work behavior (IWB)*

JEL classification: *L20, M10, M15, M21*

INTRODUCTION

The constant changes in the IT sector and the increasing complexity of global markets have made innovation a cornerstone of organizational success. With that being said, the ability of organizations to embrace innovative leadership – a style that empowers innovation (Zhu et al., 2024), and innovative work behavior (IWB) – a series of actions undertaken by an individual to foster, support and implement incremental innovations in the workplace (de Jong & den Hartog, 2008), is at its peak of importance. Findings by Hernaus, Černe and Vujčić (2023) indicate that organizations achieve the greatest benefits when both supervisors and employees demonstrate creativity and innovation. Research has shown that various factors influence individual creativity and innovative behavior, with leadership behavior being one of the most significant ones (Jyoti & Dev, 2015). Therefore, understanding how leadership impacts individual innovation is crucial from a theoretical and practical perspective. Numerous studies on various leadership philosophies, including transformational leadership (Arnold, 2017), charismatic leadership (Boerner et al., 2008), and strategic leadership (Jansen, Vera & Crossan, 2009) have been conducted. Each leadership style has played a significant role in enhancing our

understanding of effective leadership across various organizational contexts. However, innovative leadership is still gaining increasing attention, making it an essential area for further research. Zhu et al. (2024) recently introduced the Innovative Leadership Measure (ILM), creating a solid ground for its further empirical exploration.

Zia et al. (2024) found that job resources positively influence IWB, with engagement and leadership playing significant roles in this relationship. Several authors have studied the connections between IWB, work engagement and job design, covered in this research. Nathaniel and Dewi (2024) observe that job autonomy significantly improves IWB, while work engagement fully mediates the effect of job crafting on IWB. Elamin et al. (2024) conclude that employee engagement positively affects IWB. Karafakioglu and Findikli (2024) found that work engagement positively mediates the link between digital leadership and IWB. Moreover, Helmi and Azmy (2023) highlight that leadership support is vital for encouraging IWB, enabling employees to drive innovation, and ensuring long-term success. However, the real-life problem is the challenge IT organizations face in fostering and maintaining IWB among employees. This is critical for their survival and competitiveness in a rapidly evolving industry characterized by constant technological advancements, intense competition, and the need for continuous innovation, requiring both creative employees and leaders who can effectively inspire, support and manage innovation. Studying the impact of leadership is crucial, as leaders must balance job demands and resources in order to sustain employees' motivation, as well as productivity by effectively managing these influences.

Shafi et al. (2020) highlight that transformational leadership is related to IWB through fostering employees' creativity, while Mehboob and Haque (2024) suggest that empowering leadership supports IWB by encouraging job crafting and motivating employees to engage in innovation. Although these leadership styles share similarities with innovative leadership, research confirms that they are empirically distinct (Zhu et al., 2024), underscoring the need to examine innovative leadership separately. AlEssa and Durugbo (2022) further emphasize the importance of exploring how different leadership styles relate to IWB across industries and regions. While the relationship between leadership and IWB is recognized, the specific role of innovative leadership remains underexplored. In particular, the connection between innovative leadership and IWB, mediated by job resources, job demands and engagement, has not yet been fully examined. Innovative leaders are often viewed as drivers of creativity, but does their innovation inspire the same behavior in employees? Can innovative leadership shape employees' work engagement and encourage

IWB? These questions are especially relevant in industries such as IT, where rapid technological change requires continuous innovation.

The purpose of this study is two-fold: (1) to investigate the relationship between innovative leadership style and the IWB of employees in IT organizations; (2) to explore the mediating roles of job resources, job demands and work engagement in the relationship between innovative leadership and employees' IWB. The IT sector is a suitable area for conducting such research since its need for quick adaptation, creativity and continuous innovation to stay competitive is at the core of its operations. Thus, in order to analyze the previously mentioned relationship between the variables, we employed a path analysis on a sample of 101 employees in the leading Croatian IT companies. By combining self-determination theory (SDT) (Ryan, 2017) and Job Demands–Resources (JD-R) model (Bakker & Demerouti, 2007), this research provides additional knowledge toward a better understanding of employees' IWB. While the JD-R model explains the relationship between job demands, resources and engagement, SDT clarifies why these resources positively influence engagement and motivate employees to exhibit IWB. We expand the studies on the antecedents of employees' IWB at an individual level. The findings also contribute to the existing empirical studies on how innovative leadership relates to the IWB of employees by examining the mediating role of job resources, demands and work engagement in the setting of IT organizations. In addition, we responded to the authors' call on inquiry into potential mediators in the relationship between innovative leadership and outcomes (Zhu et al., 2024).

LITERATURE REVIEW AND THEORETICAL BACKGROUND

Innovation is the process through which individuals within a company implement and adopt new ideas (Amabile & Conti, 1999). Lee and Wong (2017) indicate that employees are crucial in driving innovation. Moreover, employees' IWB is shaped by their interactions within the organization, with leadership playing a key role (Oke, Munshi & Walumbwa, 2009). IWB involves generating new ideas and exploring opportunities (creativity-related behavior), while also enhancing individual and organizational performance through the application of new knowledge, implementation of change, and improvement of processes (implementation-oriented behavior) (de Jong & den Hartog, 2008). IWB is often viewed as the outcome of four interacting systems, which include leadership, individual, workgroup, and climate for innovation (Scott & Bruce, 1994).

Ebrahim, Ismail, and Kassim (2023) identify leadership as a key driver of employee IWB. As times change, innovative leadership replaces traditional approaches, fostering creativity, competence and collaboration between leaders and employees (Soares et al., 2018). Innovative leadership represents a social impact process in which leaders encourage both individual and collective innovation inside a work unit or company by modeling innovative behaviors, fostering creative teams, and exhibiting their own innovative features, with cognition and characteristics being some of them (Zhu et al., 2024). Transformational and innovative leadership share similarities, but remain distinct – while transformational leadership emphasizes inspiration and intellectual stimulation, innovative leadership extends further by fostering a culture and structures that support innovation (Zhu et al., 2024). Additionally, innovative leaders are characterized by traits such as perseverance in driving innovation and a willingness to embrace trial and error, which are not central to transformational leadership. Recently, Zhu et al. (2024) introduced the concept of innovative leadership and developed the Innovative Leadership Measure (ILM). As this scale is relatively new, the authors encourage its use for further validation and assessment of its effectiveness.

Job design refers to the process of structuring and organizing job roles, tasks, responsibilities and workflows to optimize employee performance, satisfaction and well-being (Oldham and Fried, 2016). Job design, a key Human Resources Management (HRM) tool, allows managers to align job attributes with employees' needs and abilities, promoting creativity and innovation (Tims, Derks & Bakker, 2016). In their book, Hernaus and Marić (2023) explored, presented and explained in detail that job design has an indirect, yet predominantly positive impact on employee work outcomes. The JD–R model is widely acknowledged as a comprehensive framework for understanding the dynamics of workplace stress and engagement. Work engagement is defined as a “positive, fulfilling, work-related state of mind that is characterized by vigor, dedication, and absorption” (Schaufeli et al., 2003). According to Bakker and Demerouti (2007), the model posits that every profession is characterized by distinct risk factors, including job demands and job resources. Job demands are the aspects of a job that require sustained effort and may incur costs, while job resources are the elements that help achieve goals, reduce the impact of demands, and foster personal growth (Tims et al., 2016). Moreover, Bakker and Demerouti (2007) imply that job demands can cause exhaustion, while job resources positively influence an employee's work achievement.

A meta-analysis conducted by Hammond et al. (2011) highlighted autonomy and support from supervisors and coworkers (social support) as key fa-

ctors that promote innovation. Autonomy refers to the extent to which employees can decide how to do their jobs (Voydanoff, 2004). Moreover, it is essential to offer autonomy and support, as these factors enhance both idea generation and implementation (Dediu et al., 2018). Performance feedback is also relevant since it enhances work engagement and encourages innovative behavior (Eva et al., 2019). In addition, supervisory support and autonomy are critical success factors of employees' IWB (Hernaus, Dragičević & Hauff, 2024). There is no universal list of job resources or demands; each context requires tailored adjustments so as to identify the most relevant and impactful factors. Therefore, in line with previous research, we chose autonomy, performance feedback, and social support in order to conceptualize job resources in our study. The choice of those variables for measuring job resources was made because they are the variables identified in the literature as the key factors to promote innovation and are therefore important for IWB (Bakker & Demerouti, 2008). Furthermore, we defined job demands using the variables of work pressure and emotional, physical and mental demands, because these factors comprehensively capture the different challenges employees face in the workplace. Combined, these variables provide a well-rounded framework for understanding job demands and their potential impact on employees' engagement. Other scholars have also supported the use of similar characteristics for job demands and job resources, and have confirmed their validity in various contexts (Kwon & Kim, 2020).

Our research is grounded on SDT and the previously explained JD-R model. According to SDT (Ryan, 2017), work contexts that support psychological autonomy, competence and relatedness enhance intrinsic motivation and increase well-being. SDT also posits that independent variables, such as workplace context and individual differences, influence various work behaviors through mediators such as autonomy (Deci, Olafsen & Ryan, 2017).

Leadership influence is seen in various ways, as a job resource, job demand, or a factor affecting both (Tummers & Bakker, 2021). Leaders shape the work environment, impacting employee well-being and performance through job demands and resources (Breevaart et al., 2016). While studies have examined leadership styles such as transformational (Katou et al., 2022) and ambidextrous leadership (Jia et al., 2024), innovative leadership remains understudied. Fernet et al. (2015) suggest that transformational leaders reduce job demands, increase resources, and improve work attitudes. Given the similarities between transformational and innovative leadership, we hypothesize that innovative leadership will have a similar effect, leading to the following hypotheses:

H1: Innovative leadership is positively related to job resources.

H2: Innovative leadership is negatively related to job demands.

Effective leaders cultivate a work environment that enhances work engagement (Shuck and Herd, 2012). Schaufeli (2021) highlights that engaging leadership fosters work engagement by fulfilling employees' autonomy, competence and relatedness. Similarly, Alhmoud and Al-Kasasbeh (2024) highlight that transformational leadership encourages employee engagement by inspiring individuals and prioritizing their well-being, thereby creating environments that boost motivation and encourage personal and professional growth, which could also be the case with innovative leadership due to their similarities. Based on the above, we propose the following hypothesis:

H3: Innovative leadership is positively related to work engagement.

Later on, in the JD-R model, work engagement was incorporated, characterized as a psychological state that includes a sense of significance, high energy and full immersion in work (Schaufeli, 2017). Previous research has indicated that job resources, particularly social support, autonomy and feedback, are positively associated with work engagement (Mazzetti et al., 2023). Job demands were found to trigger innovative responses by workers (Janssen, 2000), however, some were found to have a motivational role (Crawford, LePine & Rich, 2010). Nevertheless, higher job resources and lower job demands were found to increase engagement (Schaufeli, 2017). As a result, we propose the following hypotheses:

H4: Job resources are positively related to work engagement.

H5: Job demands are positively related to work engagement.

Work engagement has been consistently linked to IWB (Agarwal et al., 2012). The study conducted by Koroglu and Ozmen (2022) suggests that employee engagement is positively associated with IWB. In addition, De Spiegelaere et al. (2014) observed that autonomy is related to IWB through work engagement. Therefore, the proposed hypothesis is the following:

H6: Work engagement is positively related to innovative work behavior.

According to Atiku and Van Wyk (2024), leadership practices are closely linked to both job demands and job resources, and job demands were found to fully mediate the connection between leadership practices and work engagement. With that being said, balancing resources and demands is crucial, and successful balancing is one of the predispositions of innovative behavior. Building upon the literature review and theoretical foundation, the following hypotheses were developed:

H7: Job resources mediate the relationship between innovative leadership and work engagement.

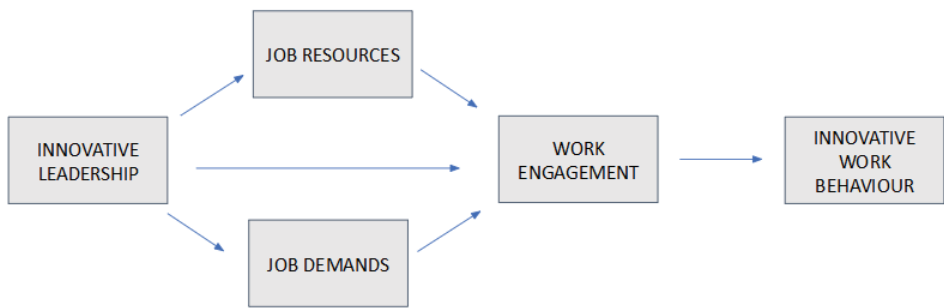
H8: Job demands mediate the relationship between innovative leadership and work engagement.

Karafakioglu and Findikli (2024) explored the mediating role of work engagement in the relationship between digital leadership and innovative behavior, finding that work engagement significantly enhances innovation within organizations. Insights provided by Alateeg and Alhammadi (2024) suggest that engaged employees are more likely to exhibit innovative behaviors, especially when supported by effective leadership. Agarwal et al. (2012) also found that work engagement mediates the relationship between Leader-Member Exchange (LMX) and IWB, and that higher levels of work engagement lead to lower turnover intentions. With that being said, we propose the following hypothesis:

H9: Work engagement mediates the relationship between innovative leadership and innovative work behavior.

Based on the formulated hypotheses, we propose the following sequential deviation model:

Figure 1. Proposed sequential deviation model



Source: Authors, 2024

DATA AND METHODOLOGY

In this study, we used a survey with validated scales to ensure reliable and consistent data collection. In that respect, six-point Likert scales, with 1 denoting *strongly disagree* and 6 *strongly agree*, were used to rate each item. The Scott and Bruce (1994) six-item scale was used to measure IWB, with sample questions including “creating new ideas for difficult issues.” A condensed form of the Utrecht Work Engagement Scale (UWES), validated by Schaufeli, Bakker, and Salanova (2003), was used to measure work engagement, including items such as “my job inspires me”, while job autonomy was evaluated with a three-item scale by Voydanoff (2004), with sample questions such as “I

have the freedom to decide what I do in my job". Social support was evaluated using a seven-item scale by Schaufeli (2015), together with questions such as "Is it sufficiently clear what you need to do in your job?", and performance feedback was evaluated using the scale by Wang et al. (2015) with sample items including "the performance feedback received from my supervisor is helpful". Work pressure was measured using the scale presented by Dolcos and Daley (2009), including sample items such as "my job requires that I work very hard". Additionally, job demands, including emotional, mental, and physical demands, were measured using the scale formed by Schaufeli (2015), with sample questions such as "Is your work emotionally demanding?", "Does your work require much attention and concentration?" and "Is your work physically demanding?". Innovative leadership was measured using the scale developed by Zhu et al. (2024), including items such as "I can tolerate potential risks that come with innovation". In line with recent findings (Amankwaa et al., 2019), we utilized self-assessment measures and requested employees to provide their personal perceptions of job resources, job demands, engagement and innovative behavior, and to report on the perceived behavior of their supervisors.

In order to verify consistency among the items, innovative leadership, job resources, job demands, work engagement and IWB, the reliability of the measurement scales was initially evaluated using Cronbach's alpha approach. As presented in the diagonal of Table 2, these scores are the following: innovative leadership (0.69), job resources (0.72), job demands (0.83), work engagement (0.80), and IWB (0.69). Although the score for innovative leadership was 0.69, slightly below the commonly accepted threshold of 0.70, this may be due to the scale's novelty, potential variability in respondents' interpretations, and because back-translation was not used in this study. Moreover, an item analysis was conducted so as to examine whether the removal of any items would increase reliability, however, no significant improvements were observed. Therefore, despite the slightly lower reliability, this scale still demonstrates acceptable internal consistency for exploratory research and provides a valuable foundation for further refinement in future studies. Eventually, the resulting values for all the other items met the minimum acceptable reliability standards, as established by Taber (2018) and Chin (2010), demonstrating the reliability and validity of the measurement scales applied in this study.

The data collection was conducted in September 2024, using a Google Forms questionnaire, and yielding a final sample of 101 valid replies (Table 1). The questionnaire was distributed via email to a curated list of the 1,000 most influential IT companies in Croatia, ensuring a targeted approach in order to gather insights from key industry stakeholders. This list was selected based

on their significant role in driving innovation within the industry, aligning with the main focus of our research. Companies were contacted via publicly available email addresses listed on their official websites, requesting that HR distribute the survey among employees. We were interested in leaders who exhibit characteristics of innovative leadership and reached out to 632 companies. As Table 1 shows, the sample is quite balanced, consisting of 56.44% women and 43.56% men. This is not in line with what one would expect from the distribution of genders in the IT industry, as there was only 17% of female employees in the IT sector across Croatia in 2023 (Statista, 2024). However, in order to get more representative results, we ensured balance between the genders. The sample consists mainly of respondents who are between 20 and 50 years of age (95.05%), whereas only a few of them are 50 years old or older (4.95%). Furthermore, most respondents have one to ten years of experience in the industry (64.36%), and are employed in the Software Development and Engineering departments (40.60%).

Table 1. Characteristics of the sample

Characteristic	Share (in %)
<i>Gender</i>	
Male	43.56
Female	56.44
<i>Age category</i>	
Individuals in their twenties (20-29)	39.60
Individuals in their thirties (30-39)	25.74
Individuals in their forties (40-49)	29.70
Above 50 years of age	4.95
<i>Years of education</i>	
Spanning one to five years (1-5)	33.66
Spanning six to ten years (6-10)	30.69
Spanning eleven to fifteen years (11-15)	16.83
Exceeding fifteen years (>15)	18.81
<i>Job department</i>	
Software Development and Engineering	40.60
IT Support and Customer Service	21.80
Data Analysis	15.80
Management and Leadership	12.90
Web Development	5.00
Other Roles	4.00

Source: Authors, 2024

Descriptive statistics were presented first, showing the means and standard deviations for each variable. A correlation analysis followed, so as to identify associations between work engagement and IWB. Next, the confirmatory factor analysis (CFA) was conducted to evaluate the goodness of fit of our proposed sequential deviation model by comparing it to a one-factor model. Fit indices were then used to assess the model performance, including chi-square (χ^2) test-statistic, degrees of freedom (df), standardized root mean square residual (SRMR), Tucker-Lewis index (TLI), comparative fit index (CFI), Parsimony-adjusted comparative fit index (PCFI), root mean square error of approximation (RMSEA), and Akaike information criterion (AIC), as per Tabachnick and Fidell (2019).

In order to further examine the complex links between innovative leadership, job resources, job demands, work engagement and IWB, path analysis was conducted (Kline, 2015; Kaplan, 2008). This method is particularly suitable for understanding the direct and indirect effects of innovative leadership on work engagement and, eventually, IWB (Khan, Nawaz and Khan, 2015). In doing so, it allows for the identification of mediating pathways, such as how job resources and job demands influence IWB, which are critical for explaining how leadership fosters employee engagement and creativity (Afsar et al., 2019). By quantifying the strength of these pathways, path analysis offers a thorough and accurate explanation of these dynamics, making it an effective tool for supporting the theoretical background of Bakker's and Demerouti's (2007) JD-R model, but also for explaining complex phenomena such as IWB in organizational contexts (Hair et al., 2019). Therefore, its widespread use in leadership and innovation research underscores its reliability and relevance for this study.

Aggregated measures for every construct were created. The items were combined into an individual indicator by calculating their average score, and were then subsequently utilized in the path analysis (Messmann, Evers and Kreijns, 2022). After constructing the model, fit indices, including the χ^2 -test statistic, the CFI, the non-normed fit index (NNFI), the RMSEA, and the SRMR were computed so as to quantify its fit. Using the lavaan package to build the path analysis model, this study was conducted in R statistical software, version 4.4.1.

RESULTS AND DISCUSSION

Descriptive statistics (Table 2) show that most respondents firmly believe that they are innovative, that they encourage and support the growth of new

ideas at work, and are involved in their creation ($M = 4.78$, $SD = 0.63$). In addition, they can rely on their coworkers, feel proud of their work, and have the autonomy to make their own decisions ($M = 4.61$, $SD = 0.47$). Accordingly, most respondents do not feel overburdened by the amount of work they have to complete, leading to lower ratings with regard to how difficult and draining their work is ($M = 3.39$, $SD = 0.77$). Eventually, most of the respondents feel invested in their work ($M = 4.48$, $SD = 0.53$), and are of the opinion that their work environment encourages creative work practices ($M = 4.51$, $SD = 0.57$).

The correlation coefficients revealed that innovative leadership is positively associated with job resources and adversely associated with job demands. Moreover, job resources are negatively associated with job demands, and positively associated with work engagement. Additionally, work engagement is found to have a positive association with IWB. None of the other correlation coefficients showed statistical significance. The detailed insights are unveiled in Table 2.

Table 2. Descriptive statistics and correlation tables

Variables	M	SD	1.	2.	3.	4.	5.
Innovative leadership (25 items)	4.78	0.63	(0.6933)				
Job resources (15 items)	4.61	0.47	0.40***	(0.7175)			
Job demands (7 items)	3.39	0.77	-0.44***	-0.27*	(0.8251)		
Work engagement (9 items)	4.48	0.53	0.40***	0.48***	-0.02	(0.7987)	
Innovative work behavior (6 items)	4.51	0.57	-0.02	0.11	0.04	0.30**	(0.6931)

Note: N=101

* $p<0.05$, ** $p<0.01$, *** $p<0.001$.

Source: Authors, 2024

The results of the CFA analysis suggest that the one-factor model produced poor fit statistics, while our proposed model confirmed the good model fit. The model fit measures are presented in Table 3.

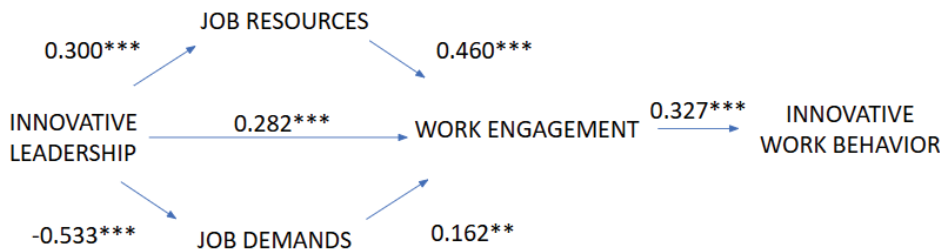
Table 3. Results of the confirmatory data analysis

CFA model	χ^2	df	SRMR	TLI	CFI	RMSEA	AIC
One-factor model	1750.320	235	0.140	0.550	0.600	0.160	1802.820
Proposed model	510.450	218	0.030	0.930	0.970	0.040	630.210

Source: Authors, 2024

In order to test our proposed model, we examined the relationships between the independent variable, the two mediators, and the dependent variables. We tested the effect of the independent variable on the first and second mediators, and the effect of the first and second mediators on the dependent variables, separately. The results confirm the sequential mediation process, as outlined in our hypotheses. The resulting path diagram, along with the designated direct and indirect effects, is displayed in Figure 2. All path coefficients of the model are statistically significant at the 0.05 level (Table 4). The findings indicate that for every one-unit rise in innovative leadership, job resources rise by 0.300, while job demands decrease by 0.533. Furthermore, for every one-unit rise in job resources, work engagement rises by 0.460, whereas for every one-unit increase in job demand, work engagement rises by 0.162. Furthermore, for every one-unit increase in innovative leadership, work engagement rises by 0.282, and by every one-unit rise in work engagement, IWB rises by 0.327. These results highlight the mediating role of job resources and job demands in linking leadership to work engagement, and prove the positive influence of work engagement on IWB.

Figure 2. Model with standardized path coefficients



*p < 0.1, ** p < 0.05, ***p < 0.01.

Source: Authors, 2024

Table 4. Path standardized coefficients based on the model

Dependent variable	Independent variable	Estimate	Standard error	p-value
Direct effect				
Innovative work behavior	Work engagement	0.327***	0.101	0.001
Indirect effect				
Job resources	Innovative leadership	0.300***	0.068	0.000
Job demands	Innovative leadership	-0.533***	0.109	0.000
Work engagement	Innovative leadership	0.282***	0.082	0.001
	Job resources	0.460***	0.101	0.000
	Job demands	0.162**	0.062	0.009

*p < 0.05, ** p < 0.01, ***p < 0.001.

Source: Authors, 2024

The final model had an excellent fit, with $\chi^2 = 92.638$, $p < 0.0001$, CFI = 0.998, TLI = 0.994, RMSEA = 0.023, 90% confidence interval around RMSEA of 0.000 to 0.154, and SRMR = 0.048.

The objective of this study was to explore the relationship between innovative leadership and IWB of employees through job resources (autonomy, social support, performance feedback), job demands (work pressure, emotional exhaustion, mental exhaustion, and physical exhaustion) and work engagement. Using the proposed model, all the hypotheses (H1–H9) were confirmed, providing empirical evidence for the relationships between variables.

We found that innovative leadership is positively related to work engagement by enhancing job resources. These results are consistent with earlier studies on transformative leadership and the manner in which it affects employee engagement at work (Bakker and Demerouti, 2017). Such connection is not surprising, since innovative and transformational leadership share key similarities, as they both emphasize fostering change, encouraging creativity and inspiring individuals. Job resources have consistently been shown to be the most important factor and a key strategy in driving engagement, because they support workers in managing the demands of their jobs and promote learning and personal development (Mazzetti et al., 2023). This aligns with the SDT, where autonomy-supportive conditions fuel intrinsic motivation, leading to greater IWB.

Additionally, it has been observed that innovative leadership is negatively related to job demands, which positively relate to employee engagement. This relationship can be understood through the lens of problem-focused coping in

the workplace, where leaders actively address challenges and provide solutions, thus enabling employees to feel more capable and supported in tackling their tasks. Lower job demands might not be the most effective approach to higher employee engagement, leading instead to the point that maintaining an optimal level is critical, as excessive reduction may undermine employee engagement, whereas a balanced demand level fosters challenge and stimulation (Einarsen et al., 2018). Combined, these dynamics highlight how innovative leadership not only eases the strain of job demands, but also transforms them into opportunities for growth and engagement.

Our results show that perceptions of innovative leadership are positively related to work engagement through job resources and job demands. In addition, work engagement is positively related to IWB. This supports the observations of Hernaus and Marić (2023), by indicating that job design has an indirect, but positive impact on employee work outcomes. Furthermore, Karafakioglu and Findikli (2024) confirm that work engagement plays a mediating role in the relationship between leadership and employees' innovative behavior, which is consistent with our findings. In addition, Nathaniel and Dewi (2024) observe that work engagement mediates the relationship between job autonomy and IWB. Moreover, our results align with those of Khalili (2017), indicating that innovative leadership behavior has a significant positive impact on innovation in the workplace. Supervisors should provide employees with the information needed to foster creativity and innovation, they must support and acknowledge employees' initiatives and efforts (Bos-Nehles & Veenendaal, 2019). Eventually, our results further contribute to the findings of Hernaus, Dragičević and Hauff (2024), indicating supervisory support and autonomy as the critical success factors of employees' IWB.

IMPLICATIONS

This study yields important theoretical contributions. It empirically validates the role of innovative leadership concerning work engagement and IWB. Additionally, the insights support the usefulness of the JD-R model in understanding how job resources, demands, and work engagement are related to fostering innovation. The study also highlights the use of the newly developed ILM by Zhu et al. (2024), showcasing its potential for future research. Findings emphasize the need for leaders to adopt innovative leadership practices that encourage IWB by promoting autonomy, providing constructive feedback, and creating a supportive work environment.

LIMITATIONS AND FUTURE RESEARCH

Despite its contributions, this study has several limitations. The small sample size (N=101) limits generalizability beyond the IT sector, and self-reported data may distort results. Future studies should use a larger, more diverse sample, and should include additional data sources. The focus on IT reduces applicability to other industries, therefore research across sectors is necessary. Additionally, the use of cross-sectional, single-source data limits the findings, and longitudinal data would provide a more comprehensive understanding of the relationships over time.

CONCLUSION

Our analysis contributes to the literature on innovative leadership by examining its relationship with job resources, job demands, work engagement, and IWB. As previously noted, innovative leadership is positively related to job resources such as autonomy and social support, while it is negatively related to job demands such as work pressure and exhaustion. In turn, job resources and demands are positively linked to work engagement. Employees led by innovative leaders are more likely to be resourceful and innovative. Organizations aiming to foster a culture of innovation should prioritize this leadership style. Providing the right support, resources, and an environment that encourages creativity, can establish innovation as a core aspect of the workplace.

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CO-CREATING VALUE ON SHARING ECONOMY PLATFORMS: EXPLORING THE ROLE OF DIGITAL TRUST

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The sharing economy, which is increasingly developing in the modern society, is based on the joint use of various resources via digital platforms. More and more companies are utilising the business models of the sharing economy, in which user participation in shared value creation is crucial. In the theory of service-dominant logic, value co-creation is a process in which the consumer becomes an active co-creator of value (of the product or service) in collaboration with the company. In the context of the sharing economy, value co-creation is a collaborative process in which both users and service providers contribute to shared value creation via platforms. Digital trust is essential for value co-creation, because trust in technological structures, transaction security, and service quality primarily enable users to share resources with each other in a secure and reliable manner, and to create value in the process of co-creation. The main objective of this paper is to investigate the determinants of digital trust among sharing economy platform users and to analyse the impact of digital trust on value co-creation. An analysis of previous research was conducted and a structured questionnaire was created. The empirical research was conducted on a sample of 541 users of sharing economy platforms. Univariate and multivariate statistical methods were used for data processing. Hypothesis testing was performed using the partial least square structural equation modelling (PLS-SEM). The research results show that privacy, security and reliability are significant predictors of platform-based trust and trust in structural assurance. The research results also suggest that

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platform-based trust and trust in structural assurance have a statistically significant and positive influence on value co-creation through sharing economy platforms. This study contributes both to theory and practice. From a theoretical perspective, it complements knowledge in the field of consumer behaviour. Factors that influence digital trust were identified and the willingness to co-create value on sharing economy platforms was determined. The practical contribution of the paper is reflected in a clear understanding of the actual behaviour of sharing economy platform users, enabling service providers to develop effective digital marketing strategies to fulfil user expectations and build long-term relationships based on digital trust.

Keywords: *Sharing economy platforms, value co-creation, digital trust*

JEL classification: *M30, M31, O10*

INTRODUCTION

The intensive development of digital technology has made it possible for sharing economy platforms to become a space that enables users to share various resources, actively shape supply and demand, and jointly participate in value creation. The development of digital platforms has made it possible to connect individuals and organisations, and provide them with opportunities for mutual exchange of resources and value co-creation (Nadeem et al., 2020), leading to users' desire for improved value distribution (Tumaku et al., 2023), greater efficiency of products and services (Surmacz et al., 2020), improved market performance, and the creation of competitive advantage (Li and Tuunanen, 2022).

Recent studies identify the key factors as prerequisites for value co-creation on digital platforms, specifically relating to user trust in the platform and engagement (Shah et al., 2021). In addition, Khodayari et al. (2025) emphasise that trust-building mechanisms are pivotal for fostering long-term engagement on SE platforms. Previous research has explored the concept of trust and its relationship to satisfaction, loyalty, behavioural intentions and word of mouth in sharing economy platforms (Gu et al., 2021; Alamoudi et al., 2023; Amrolahi et al., 2024). However, Jang and Lau (2021) pointed out that research on security risks and trust is scarce and insufficient, especially in the context of platform-based trust and trust in structural assurance, which is of particular importance for emerging countries (Surmacz et al., 2024). In developing countries, such as the Republic of Croatia, digital platforms stimulate economic

growth by expanding market access, creating jobs and strengthening digital literacy (Dahmani and Ben Youssef, 2023).

Although previous research has provided insights into the topics of digital trust (Liang et al., 2018; Yang et al., 2019; Jiang and Lau, 2021; Shah et al., 2021; Tumaku et al., 2023) and value co-creation in the sharing economy (Camilleri and Neuhofer, 2017; Nadeem et al., 2020; Wang et al., 2020; Nadeem et al., 2021; Nadeem and Salo, 2023), there is a lack of research that explores the relationship between digital trust and value co-creation on sharing economy platforms. This research will, therefore, attempt to close the aforementioned research gap.

The purpose of this study is to investigate the determinants of digital trust and value co-creation among the users of sharing economy platforms. The present paper has three main objectives. The first is to explain the notions of the basic concepts of digital trust and value co-creation, and the second is to establish a conceptual model of the interdependence of digital trust and value co-creation. The third is to determine the relationship between privacy, security, fulfilment, digital trust and value co-creation in terms of sharing economy platforms.

CONCEPTUALIZATION AND HYPOTHESES DEVELOPMENT

The fundamental prerequisite for trust in sharing economy platforms is the protection of privacy and personal data, as it allows users to share their own resources in a secure manner. In this paper, privacy is considered as “the extent to which a user considers that his or her information is protected and will not be misused” (Shin, 2019: 4). These platforms require a high level of disclosure of private data, especially from service providers, in order to attract potential users (Chen et al., 2022). Previous research (Kong et al., 2019; Yang et al., 2019; Li and Wang, 2020; Ariesty and Ikhsan, 2021; Amrollahi et al., 2024) has shown that security and privacy are the strongest predictors of trust in sharing economy platforms. In the context of Airbnb, Yang et al. (2019) have shown that users perceive this platform as a secure environment for sharing private information and transactions, emphasising the extremely significant relationship between privacy, security and trust in Airbnb. In addition, Lutz et al. (2017) found that the privacy assurance of sharing economy platforms significantly influences trust and reduces privacy concerns. The following hypotheses are, therefore, suggested:

H_{1a}: Privacy positively influences platform-based trust.

H_{1b}: Privacy positively influences trust in structural assurance.

In the digital environment, users demand a high level of security and protection of their financial data (Belanger et al., 2002; Kong, 2019; Li and Wang, 2020). Transaction security is also a key factor in the development of trust in online purchases. It depends on the extent to which users perceive the platform as secure (Kim and Park, 2013). Ensuring reliable financial transaction methods is a prerequisite for using sharing economy platforms, as they usually involve financial transactions between unknown persons. Well-developed security systems on sharing economy platforms reduce the risk in transactions, increase the personal security of users and strengthen user confidence (Li and Wang, 2020). In an empirical study of Airbnb users, Kong et al. (2019) proved that trust in Airbnb is significantly determined by transaction security. From the perspective of providers on short-term rental sharing economy platforms, Li and Wang (2020) found that perceived personal safety systems are a significant predictor of trust in these platforms. Moreover, Ariesty and Ikhsan (2021) showed that transaction security significantly influences trust in sharing economy activities. Therefore, the following hypotheses are proposed:

H_{2a}: Security positively influences platform-based trust.

H_{2b}: Security positively influences trust in structural assurance.

Fulfilment, i.e. reliability, is defined as the “degree to which consumers believe that they are able to place an order as accurately as possible on an online platform” (Nadeem et al., 2021: 424). According to the users’ expectations, the product or service should match the description and be processed quickly and efficiently (Nadeem and Al-Imamy, 2021) in order to guarantee the user a high-quality and safe experience. The ability of a platform to fulfil customer expectations and needs quickly and efficiently increases the perception of trustworthiness among customers. In e-commerce settings, previous research has shown a positive relationship between fulfilment and customer satisfaction (Lukman and Indrawati, 2024). In addition, a study by Cho (2015) confirmed a significant positive effect between order fulfilment quality perception and repurchase intention in internet retailing. In sharing economy settings, Nadeem et al. (2020) found that fulfilment has a strong impact on consumer trust. Therefore, it is assumed as follows:

H_{3a}: Fulfilment positively influences platform-based trust.

H_{3b}: Fulfilment positively influences trust in structural assurance.

There are two basic types of trust in sharing economy platforms (Liang et al., 2018): institution-based trust, which generally refers to trust in technology aspects of platforms, and disposition to trust, which refers to trust in people who provide or use products or services. As the focus in this paper is on digital trust, which primarily implies an assessment of the reliability of technology from the

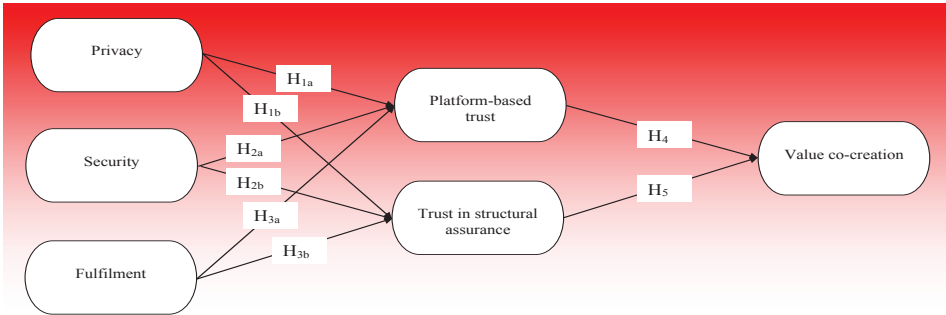
perspective of privacy and security (Shin, 2019), the following paper focuses on different aspects of institution-based trust. According to Jiang and Lau (2019), there are two approaches to institution-based trust: (1) platform-based trust and (2) trust in structural assurance. Platform-based trust implies that the user is willing to rely on the trading partner, i.e. the platform that he or she uses to share a product or service (Nadeem and Al-Imamy, 2020), and relies on the competence, reliability and helpfulness of the platform (Aityoussef and Belhcen, 2022). Amaoko et al. (2021) emphasised that there is a strong interdependence between platform-based trust, credibility and benevolence: a satisfied user will develop a higher level of benevolence and trust in the platform's competence if the guaranteed product or service is of high quality and honest. Trust in structural assurance refers to the belief that the platform has developed protective mechanisms in the form of technological and/or legal structures that ensure the security of sharing economy platforms (Kang et al., 2016). Sharing economy platforms can provide privacy and security guarantees, community rules and various safety assurances (ter Huurne et al., 2017, Lu et al., 2010), which influence the users' perception of the platform's security features (Jiang and Lau, 2019).

Value co-creation refers to the process in which the consumer actively collaborates with the company and becomes an actor in co-creating the value of the product or service both for themselves and for other consumers (Lush et al., 2008; Vargo et al., 2008). The expansive use of information technology has contributed to the process of co-creation, in which the user is seen as an active participant in the co-creation of value. In this way, users who constantly create value together with companies and other users become important actors in the sharing economy settings (Nadeem et al., 2020). The special feature of the value co-creation process in the digital environment is "co-created value in use", which is created at the moment of using information technologies (Manser Payne and Barger, 2020) and consists of people (users and service providers), technological infrastructure and shared information (Akaka and Vargo, 2014). In addition, user engagement in the process of value co-creation on sharing economy platforms highly depends on the existence of trusting relationships and a secure environment (Shah et al., 2021). Wang et al. (2020) studied the relationship between privacy control, trust and value co-creation on social commerce platforms. They showed that consumers' perceived privacy control affects their trust, which in turn influences value co-creation. Also, Nadeem et al. (2020) found that trust has a positive influence on the intention to co-create value. Therefore, the following hypotheses are suggested:

H₄: Platform-based trust positively influences value co-creation.

H₅: Trust in structural assurance positively influences value co-creation.

Figure 1: The conceptual model



RESEARCH METHODOLOGY

MEASURES

A three-part questionnaire was created. In the first part, exclusion questions were asked about the respondents' age and previous experience of using sharing economy platforms over the past year. The second part of the questionnaire consisted of six groups of structured questions. The first three groups of questions related to the respondents' attitudes towards privacy, security and the order fulfilment of sharing economy platforms. The statements were taken from previous research by Nadeem et al. (2021). The fourth and fifth set of questions measured the respondents' attitudes towards platform-based trust and trust in structural assurance. The statements were adopted from previous studies by Nadeem and Al-Imamy (2020) and Kong et al. (2019). The sixth set of questions included the respondents' attitudes towards value co-creation in sharing economy platforms. This set of questions was borrowed from previous research by Shah et al. (2021). Respondents rated the statements on a 5-point Likert scale (ranging from 1 – "strongly disagree" to 5 – "strongly agree"). The third part of the questionnaire relates to the socio-demographic data.

SAMPLE AND DATA COLLECTION

This study used a survey method and the research instrument was a structured online questionnaire. The research was conducted in 2023 on a convenience sample of Croatian citizens, who had used one of the sharing economy

platforms in the past year. Furthermore, this study only included younger respondents, specifically Generation Z and Millennials. Although previous research has defined the age boundaries of these generational groups differently, most scholars agree that members of Generation Z were born in the period from 1995 to 2010 and Millennials were born in the period from 1980 to 2000 (Fan et al.; Martinović et al.; 2023; Pham et al.; 2021). The study of these age groups seemed justified, as the use of sharing economy platforms in Croatia has only increased in recent years (Dumančić and Čeh Časni, 2021) and young people, especially Generation Z, are fluent in new technologies and tend to adapt quickly to innovations (Surmacz et al., 2024). Research in many countries has also focused on these generations, among whom the concept of the sharing economy is very popular in many countries (Martinović et al. 2023). A total of 541 fully completed and valid surveys were collected.

Univariate and multivariate statistical methods were used for data processing. Hypothesis testing was performed using PLS-SEM (partial least square structural equation modelling) with SmartPLS 4.0.

RESEARCH RESULTS

The sample consisted of 54.9% female and 45.10% male participants. The majority of them were between 18 and 25 years old (69.5%), followed by respondents aged 26 to 35 years (19.41%), and 36 to 43 years (11.09%). The majority of the respondents had a secondary school degree (42.7%), followed by respondents with an undergraduate degree (38.63%) and a graduate degree (17.19%). The majority of the respondents were students (52.5%) and employed (43.62%). A total of 27.91% of the respondents have an average monthly income of €801 to €1300, 20.7% of the respondents have a monthly income of €471 to €800, while 19.59% of the respondents have an average monthly income of up to €220. This is followed by respondents with a personal income of €221 to €470 (16.64%), and only 11.09% of respondents with a personal income of more than €1301.

MEASUREMENT MODEL RESULTS

The results of the measurement model are presented in Table 1.

Table 1: Results for the measurement model

CODE	CONSTRUCT / ITEM	Outer loadings	Cronbach's Alpha	Composite Reliability	AVE
PRIVACY (PR)					
PR1	“Without the consent of consumers, this SEP will not use personal information for purposes other than for the original transactions”.	0.927	0.912	0.945	0.850
PR2	“This SEP guarantees that personal information of consumers will be handled in accordance with a third party’s privacy-protection regulations and has acquired authentication knowledge”.	0.940			
PR3	“This SEP will not apply special technology to collect and analyze the internet behavior and shopping habits of consumers without their consent”.	0.898			
SECURITY (SEC)					
SEC1	“The e-payment system of this SEP is safe and verified”.	0.956	0.905	0.954	0.913
SEC2	“This SEP guides consumers to correct and safe payment steps”.	0.955			
FULFILMENT (FUL)					
FUL1	“Consumers receive products/ services that are ordered online, matching the description on this SEP”.	0.933	0.841	0.926	0.863
FUL2	“This SEP guarantees that products/services ordered online are authentic and not imitations”.	0.925			

CODE	CONSTRUCT / ITEM	Outer loadings	Cronbach's Alpha	Composite Reliability	AVE
PLATFORM-BASED TRUST (TR_PLB)					
TR_PLB1	“The SEP is competent and effective in providing its services”.	0.915	0.916	0.947	0.856
TR_PLB2	“I would characterize the SEP as honest”.	0.931			
TR_PLB3	“The SEP is trustworthy”.	0.929			
TRUST IN STRUCTURAL ASSURANCE (TR_SA)					
TR_SA1	“I believe the SEP has enough safeguards to make me feel comfortable using it”.	0.913	0.928	0.949	0.822
TR_SA2	“I feel assured that legal and technological structures adequately protect me from problems on the SEP”.	0.914			
TR_SA3	“I feel confident that encryption and other technological advances on the SEP make it safe for me to use”.	0.919			
TR_SA4	“In general, the SEP provides a robust and safe environment to share private information”.	0.881			
VALUE CO-CREATION (COCR)					
COCR1	“I tell the service provider how to fulfil my needs better through the SEP”.	0.865	0.893	0.918	0.652
COCR2	“I tell the service provider how to improve his/her service when I feel it through the SEP”.	0.861			
COCR3	“The service provider improves his/her services when I give comments through the SEP”.	0.828			
COCR4	“I notify the service provider about the problem even if the problem does not affect me”.	0.749			
COCR5	“I appreciate the service provider if he/she gives me good service through the SEP”.	0.786			
COCR6	“Even if the price error benefits me, I will still remind the service provider”.	0.749			

Source: Author

It is evident that the values of the item loadings of the manifest variables are between 0.749 and 0.927, which means that they exceed the threshold value of 0.708 (Hair et al., 2014) and are considered valid for further analyses (Hair et al., 2014). The values of the Cronbach's alpha coefficient are between 0.841 and 0.928, and thus above the threshold value of 0.7. The values of the composite reliability (CR) are above the critical value of 0.7 (Hair et al., 2011) and range from 0.918 to 0.954, which indicates a high reliability of the constructs. The average variance extracted (AVE) values for all latent constructs are also above the critical value of 0.5 (Hair et al., 2014), which confirms the convergent validity.

The results of discriminant validity are shown in Table 2.

Table 2: Discriminant validity

	COCR	FUL	PR	SC	TR_PLB	TR_SA
COCR	0.808					
FUL	0.663	0.929				
PR	0.634	0.705	0.922			
SC	0.612	0.765	0.708	0.955		
TR_PLB	0.731	0.744	0.676	0.723	0.925	
TR_SA	0.760	0.763	0.726	0.705	0.830	0.907

Source: Author

From the table above, it can be concluded that the Fornell-Larcker criterion is fulfilled, as the results show that the square roots of the AVE values are greater than the construct's highest correlation with other latent variables. In addition, the HTMT values are between 0.676 and 0.898, which is below the threshold value of 0.9 (Henseler et al., 2015) and confirms the discriminant validity of the model.

The variance inflation factors (VIF) were used to assess the multicollinearity between the latent constructs (Table 3).

Table 3: Variance inflation factors

	COCR	FUL	PR	SC	TR_PLB	TR_SA
COCR						
FUL					2.768	2.768
PR					2.301	2.301
SC					2.795	2.795
TR_PLB	3.217					
TR_SA	3.217					

Source: Author

The table shows that the values of the VIF coefficient are between 2.301 and 3.317, which is below the threshold value of 5, and indicates that there is no problem of collinearity between the latent constructs.

STRUCTURAL MODEL RESULTS

After the fulfilling the requirements for the reliability and validity of all constructs of the model, the evaluation of the structural model was continued. The evaluation of this model was assessed by calculating the path coefficients and significance levels for testing the hypotheses (Table 4).

Table 4: Hypotheses testing

Path	Path coefficients	t-values	p-values	Hypothesis
PR → TR_PLB	0.205	4.600	0.000	H _{1a} : supported
PR → TR_SA	0.320	7.201	0.000	H _{1b} : supported
SC → TR_PLB	0.288	5.773	0.000	H _{2a} : supported
SC → TR_SA	0.162	3.522	0.000	H _{2b} : supported
FUL → TR_PLB	0.379	7.769	0.000	H _{3a} : supported
FUL → TR_SA	0.414	8.942	0.000	H _{3b} : supported
TR_PLB → COCR	0.322	5.511	0.000	H ₄ : supported
TR_SA → COCR	0.493	8.516	0.000	H ₅ : supported

Source: Author

According to Table 4, privacy ($\beta=0.205$, $p<0.05$), security ($\beta=0.288$, $p<0.05$) and fulfilment ($\beta=0.379$, $p<0.05$) have a significant and positive effect on platform-based trust, hence H_{1a}, H_{2a} and H_{3a} are supported. In addition, privacy ($\beta=0.320$, $p<0.05$), security ($\beta=0.162$, $p<0.05$) and fulfilment ($\beta=0.414$, $p<0.05$) have a significant and positive effect on trust in structural assurance, confirming hypotheses H_{1b}, H_{2b} and H_{3b}. Similarly, platform-based trust ($\beta=0.322$, $p<0.05$) and trust in structural assurance ($\beta=0.493$, $p<0.05$) have a significant positive effect on value co-creation. This results support hypotheses H₄ and H₅.

In addition, the coefficient of determination (R^2) was used to evaluate the structural model. The R^2 values show that the endogenous variables (platform-based trust (62.9%) and trust in structural assurance (66.2%)) are moderately explained by the exogenous variables (privacy, security and fulfilment). Furthermore, R^2 value for the value co-creation variable is 61.0%, which indicates

that this variable is moderately explained by the variables of platform-based trust and trust in structural assurance.

DISCUSSION AND CONCLUSION

The main aim was to identify the connection between digital trust and value co-creation in terms of sharing economy platforms. Factors that influence digital trust were identified and the willingness to co-create value on sharing economy platforms was determined. This study complements the literature in the field of consumer behaviour and fills a research gap by providing a more detailed understanding of the relationship between privacy, security, platform-based trust, trust in structural assurance and value co-creation in the sharing economy. In addition, this study contributes to the expanding body of knowledge in the sharing economy literature and marketing practices so as to better understand what drives the value co-creation process on SE platforms. Although previous research has examined digital trust in the context of SE platforms, to the author's knowledge, this study is the first to examine the relationship between the various dimensions of digital trust and user participation in value co-creation. The latter refers to the Republic of Croatia in particular, which could provide a starting point for future research.

In the conducted research, a positive and significant relationship between privacy, platform-based trust and trust in structural assurance was found, which is consistent with the findings of Yang et al. (2019) and Lutz et al. (2017). Consistent with the conclusions of Wang et al. (2020), privacy control in a social commerce community is an important predictor of user trust. Based on the results obtained, security is a significant predictor of platform-based trust and trust in structural assurance, which is in line with the findings of Kong et al. (2019), Li and Wang (2020) and Ariesty and Ikhsan (2021). Alamoudi et al. (2023) confirmed that institutional trust mechanisms (secure payment, feedback and protection mechanisms) positively influence users' perception of the security and reliability of SE platforms, and their continuous usage intention. In addition, the results suggest that the fulfilment or reliability of sharing economy platforms is an important factor that influences user trust. Users receive authentic products or services that are guaranteed to them, which leads to a positive perception of platform quality and, consequently, to greater trust. The study also proves the positive influence of platform-based trust and trust in structural assurance on value co-creation. Wang et al. (2020) also demonstrated that users' intention to co-create value is greater when they have a

higher level of trust in social commerce. In the context of platforms such as Airbnb and Uber, Amrollahi et al. (2024) have shown that structural security (such as platform transparency) and perceived privacy protection are important predictors of digital trust, leading to the continued use of these platforms. When users trust these platforms, their satisfaction is higher, which leads to the continued use of these platforms (Tumaku et al., 2023), and can also stimulate the process of value co-creation.

The practical contribution of the paper is reflected in a clear understanding of the actual behaviour of sharing economy platform users, enabling service providers to develop effective digital marketing strategies to fulfil user expectations and build long-term relationships based on digital trust. It is necessary to develop a clear data protection policy based on the transparency of security and privacy measures. It is also possible to introduce an evaluation system based solely on the assessment of the technological aspects and security services of the platforms in order to collect views, opinions and suggestions on the need to improve the security and data protection system. It is also proposed to introduce various incentives in the form of discounts and vouchers that can be used for products or services when users leave a review to improve the platform's protection mechanisms. To improve the perception of the fulfilment, i.e. credibility of products and services, it is possible to introduce various user testimonials as part of highlighting the best practices.

The limitations of this study stem primarily from its purposive sampling, so the results cannot be generalized. For future studies, it is recommended to use probabilistic sampling methods to ensure greater representativeness of the sample and increase the reliability of the conclusions. Furthermore, only Croatian citizens were included in the study. Future studies should, therefore, include respondents from a wider geographical area and with different cultural backgrounds in order to be able to carry out a comparative analysis between different population groups. Furthermore, the sample is dominated by younger respondents (18 to 25 years old), while middle-aged respondents are significantly less represented. As younger people have a greater preference for and reliance on digital technologies, their perception of digital trust may differ significantly from that of middle-aged individuals. Future research should include a more even distribution of the sample in terms of age, education and income so as to gain a deeper understanding of the dimensions of digital trust and the tendency to co-create value. Therefore, future research should investigate the attitudes of middle-aged users, particularly in relation to their perceptions of security and privacy on digital platforms. Furthermore, the research utilised an exclusively quantitative approach. In order to gain a more comprehensive

insight into the research topic, it is suggested to use qualitative methods (i.e. focus groups, interviews). This would allow for a more complex investigation into the attitudes of SE platform users, which would deepen the quantitative results and ensure a more comprehensive analysis of digital trust and value co-creation on SE platforms.

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DRIVERS AND BARRIERS IN THE USE OF PAYMENT INNOVATIONS BY SMALL BUSINESSES

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Small businesses make up a significant share of the economy in EU countries. The development of new models for the distribution of goods and services has contributed to the growing interest in implementing innovations in payment methods. Small businesses and their customers heavily rely on improvements in the speed, security, and convenience of payment processes. An increase in the number of supported payment methods boosts the sales of small businesses and creates opportunities for reaching diverse customer profiles. Positive effects reported by businesses include an increase in average purchase value, an increase in the number of items purchased, and the ability to identify customers and their payment history. Advantages also apply to B2B transactions and payments with government agencies and employees.

The aim of this study is to identify and analyse the drivers and barriers in the use of payment innovations in small business operations. Special attention is given to payment innovations over the past decade, with a focus on the use of digital payment forms and artificial intelligence. The COVID-19 pandemic accelerated the adoption of innovations in digital payments. The key drivers for the development of payment systems in small businesses include the potential to increase sales, attract new customers, and reduce transaction processing costs. The benefits of digital payment innovations go beyond the traditional notions of cost savings and convenience. Digital payments also contribute to greater transparency in business operations and increased revenues for the state budget.

Alongside the undeniable advantages, there are some barriers that slow down the adoption of digital payment innovations in small busi-

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nesses. The challenges include risks and threats such as hacking and cyberattacks, breaches in payment system security, technological failures, leaks of personal and sensitive information, and more. On the supply side, the main barriers are linked to the level of financial and digital literacy among entrepreneurs. On the demand side, barriers involve issues with customer knowledge, willingness, and ability to use non-traditional payment methods.

In conclusion, the accelerated adoption of innovative payment methods is identified as a crucial factor for enhancing the competitiveness of small businesses by creating alternative payment options for both businesses and end customers.

Keywords: *Payment innovations, digitalization, small business*

JEL classification: *G29, O30*

INTRODUCTION

Payment innovations have been developing at an unprecedented pace in the recent decades. The boom in information and communication technologies has found suitable ground for application in the field of payments. The global COVID-19 pandemic has played the role of a catalyst for these processes. Digital payments have received a strong impetus for development in the conditions of lockdown. The pandemic has actually turned out to be an accelerator for changes in payments. For small businesses, innovations in payments are not only an opportunity, but also a necessity for business development and growth.

Innovations in payments can be categorized into three levels: changes in how payment services are linked to accounts, changes in the systems that process payment transactions, and changes in how users interact with payments and the business model of payment service providers (World Bank Group, 2022). Modern innovative payment methods are inextricably linked to digital internet-based platforms.

The key drivers of the development of digital payments are new technologies, consumer demand, and regulatory drivers (Infosys, 2019). Consumer demand is focused on the possibilities for real-time payments, user experience, and personalization. The main regulatory act is the Revised Payment Service Directive, which regulates payment services and payment service providers throughout the European Union (EU) and the European Economic Area (EEA). Various aspects of current payment habits of citizens of the euro area

countries are being examined, and specifically their attitudes towards digital payment methods and the user perspective on new digital payment methods (Kantar Public, 2022). Payments transformation is considered to be the biggest challenge that many banks will be facing in the coming years (Icon Solutions, 2019).

Innovations in payments are largely related to the digitalization of payment services. Digital payments in the global network allow entrepreneurs to attract new customers and increase their sales by creating online stores for the sale of their goods and services. The use of cashless payment services provides access to various financial packages and services offered by banks and other financial intermediaries, such as deposits, loans, insurance, etc. Furthermore, the remuneration of employees in the company, payments to suppliers, as well as taxes and other obligations to the state budget can be paid electronically.

Innovations in payments have become part of the daily life of a large part of entrepreneurs in the field of small business. It has become clear that those who stubbornly refuse to accept innovative forms of payments risk finding themselves on the losing side. There are still too many challenges in this area of business due to reasons of a different nature – lack of bank accounts of entrepreneurs, customers or contractors, lack of mobile services, modems and other digital devices and, in general, lack of the necessary payment infrastructure.

THEORETICAL BACKGROUND

The increase in the share of digital payments compared to cash payments leads to cost savings and the possibility of increasing trade turnover. In addition to the convenience and speed of implementing and processing transactions, an advantage of digital payments is the transparency of cash inflows and outflows (Khando et al., 2023). The connectedness between digital payment systems and accounting software allows for the traceability of transactions and enables an analysis of sales by product groups. The use of digital payment forms also significantly reduces manual manipulations, thus reducing the time, effort and costs of entrepreneurs and, according to studies, it is three times more effective than traditional methods (Deloitte, 2018 – as cited in Klapper, 2023).

The use of innovative forms of payments leads to the traceability of cash flows, and hence to significant “lightening” of the business. Since digital transactions provide accurate and reliable information on sales and trade turnover, this helps to establish the financial status of the merchant (Khan & Siddiqui,

2019). This, in turn, is a prerequisite for obtaining a good credit history and rating, and facilitates entrepreneurs' access to various financial services offered by banks and other financial intermediaries. The highest priority for small businesses is access to bank loans, and various support and financing programs.

Cash payments are prevalent in small businesses. Their popularity is primarily due to the preferences of traditional clientele. Businessmen often consider them more attractive because they enable them to avoid paying transaction processing fees and allow for the concealment of turnover. However, keeping significant cash balances in cash registers increases the risk of theft and abuse. Physical transfer of cash also carries risks of fraud and robbery.

Weak or missing technical and technological infrastructure, especially in sparsely populated and remote areas, can be a serious problem for the development of innovative forms of payments. Investments in infrastructure are crucial in this regard (Ulas, 2019). They are objectively necessary, but at the same time insufficiently effective in terms of the cost-benefit ratio. Unstable internet connection and poor mobile coverage can undermine trust in the use of digital forms of payments if they are associated with frequent crashes and interruptions, which leads to difficulties or impossibility of carrying out digital transactions.

One of the frequently cited arguments against the introduction of innovative forms of payment are the high transaction costs associated with paying fees to financial intermediaries for the execution and processing of transactions. Merchants pay fixed service fees to payment service providers and variable fees depending on the number or value of transactions. In this regard, blockchain and Distributed Ledger Technology (DLT) can be used as a suitable infrastructure that eliminates intermediaries in payment systems and reduces transaction costs (Petrov, 2019). Blockchain technology has great potential for decentralization, transparency and automation, which is expected to improve the payment process by making it faster, with lower costs and increased resilience to cyberattacks.

Machine-to-machine (M2M) automated payments in combination with the Internet of Things (IoT) devices could contribute to the automation of payment processes in the future and could significantly increase their efficiency (ECB, 2023). Another innovative form of expanding the payment network among small businesses are QR codes. Their significant advantage is the ability to initiate payments from a mobile device, which does not require additional investment in technical equipment. Even a printout may be sufficient to make a payment by scanning the code. Currently, the main barrier to the mass use of

QR codes is the lack of unification and operational compatibility of the codes (World Bank Group, 2022).

Low financial literacy among entrepreneurs and their customers is a factor that can hinder the introduction of innovative forms of payments. According to the results of a study conducted in 140 countries, only 33% of entrepreneurs surveyed have a satisfactory level of financial literacy (Microsoft Singapore and the Association of Small & Medium Enterprises, 2020 – as cited in Klapper, 2023). Low financial literacy is an obstacle to the use of financial services and negatively affects the ability of entrepreneurs to make adequate financial decisions.

Innovative payments are associated with the use of new technologies and as such they are not insured against various types of risks. Some of them arise from technical problems – system failure due to overload, lack of power supply or other reasons. However, others are due to intentional interference. For example, digital payment systems can be subject to hacker cyberattacks (Klapper, 2023). In such circumstances, entrepreneurs are threatened not only by financial losses, but also by the leakage of sensitive information and data about their business. This raises the question of the reliability and security of payment systems and measures to counter cyber threats.

Tables 1 and 2 summarize the key findings and results from studies focused on payment innovations in business as a whole, and specifically in the small business sector. The results from the analysed secondary sources of information are divided into two periods – before and after the global COVID-19 pandemic.

Table 1: Findings and results from studies conducted up to 2020

Source/ Years	Main focuses	Conclusions and results
Payments Innovation Jury Report (2015)	Innovations, mobile money, payments, cryptocurrencies and the blockchain architecture	The high level of charges and relatively poor levels of service make business customers, especially SME's, receptive towards lower costs and more efficient international solutions.
World Bank Group (2016)	Obstacles and incentives for the adoption and use of electronic payments from the perspective of micro, small and medium retailers	Six obstacles are identified in this research: 1. An inadequate value proposition for merchants. 2. Weak product and stakeholder economics in traditional card models. 3. Insufficient aggregate customer demand. 4. Inconsistent technological infrastructure and regulatory environment. 5. Ineffective distribution models. 6. Difficulty in formalizing enterprises and reluctance of merchants to pay full taxes on sales.
KPMG (2019)	Predictions of how the payments world will look in 2030	1. Nation-states will launch their own digital currencies to retain control of economic policy. 2. Regulators will police payments processes rather than providers. 3. The payments value chain will be built on data. 4. Almost every citizen will have their own biometrically-enabled digital ID. 5. Payments technology will drive down financial exclusion. 6. The social experience will converge with payments technology. 7. Distributed ledger technologies will underpin a globally connected, high-speed payments network. 8. Real-time payments will become the norm, even for cross-border transactions. 9. Payments ecosystems will evolve from collaboration between new entrants and incumbents.

In the years before the global pandemic, high implementation and operational costs, underdeveloped payment infrastructure, and still-insufficient demand were the main barriers to the growth of innovative payments, negatively impacting the efficiency of payment processes. Against this backdrop, whether surprisingly or not, KPMG's forecasts for 2030 (as presented in Table 1) turned

out to have a shorter horizon than expected due to the significant boost in digital payment development driven by lockdown conditions.

Table 2: Findings and results from studies conducted after 2020

Source/ Years	Main focus	Conclusions and results
Mastercard (2022)	Digital solutions enablement for small and midsize businesses (SMBs)	As a result of the conducted research, the following conclusions are drawn: 1. SMBs need better ways to pay. 2. SMBs need better ways to get paid. 3. SMBs need better access to working capital. 4. SMBs need better access to digital tools and capabilities.
Visa/ Kearney (2022)	Digital enablement of small and medium-sized businesses	The research presents several key areas in support of digitalization: 1. Create a supportive environment for SMB growth and prosperity. 2. Governments are responsible for supporting the adoption of digital tools and reducing the barriers to their adoption. 3. Design ongoing education and training programs on the benefits of digitalization.
Euromoni- tor (2023)	Digital transformation in commercial payments	Based on the analysed data, the following conclusions are made: • SMEs want to take advantage of the digital innovations in commercial payments that will simplify and better organise how they pay their suppliers. • Business owners are seeking access to invoice payment platforms, small business commercial card solutions, and travel management tools tailored to fit the needs of their distinct company characteristics.

Undoubtedly, the global pandemic acted as a powerful accelerator for innovations in the field of digital payments. The specific manifestations and outcomes of these innovations in the small business sector remain insufficiently researched. The majority of recent studies focus on the technological aspect of the issue. Challenges for small businesses include the growing consumer demand and their limited ability to quickly adapt to changes compared to corporate businesses.

RESEARCH METHODOLOGY

A methodology was developed for conducting the research, which aims to collect and analyse the information related to various aspects of the implementation of innovative payment methods by small businesses. The main goal of the study is to clarify the drivers and limitations for the development of innovative payments, and based on this, to highlight the most significant issues and opportunities for overcoming them.

Given the sensitivity of the payment topic among small businesses and the challenges of collecting data through surveys on this issue, a qualitative research method was chosen, involving in-depth personal interviews with business owners. The research of secondary information regarding small businesses and the sectors where they are most representative is a key argument for selecting the companies included in the study. Out of the 40 invited participants who matched the desired profile, 35 responded, and their business affiliation and profiles are presented in Table 3.

Table 3: Profiles of individuals (owners and managers) covered by the study, by means of the method of personal in-depth interviews

Number of interviewed individuals	Business sector and market type	Profile of interviewed individuals (gender)	Profile of interviewed individuals (age)
6	Wholesale and Retail Offline Market (4) Offline and Online Markets (2)	Male (4) Female (2)	21-35 (2) 36-45 (1) 46-60 (1) Above 60 (2)
5	Catering (Restaurants) Offline Market (4) Offline and Online Markets (1)	Male (3) Female (2)	21-35 (2) 36-45 (1) 46-60 (1) Above 60 (1)
4	Hospitality (Hotels) Offline and Online Markets (4)	Male (2) Female (2)	36-45 (2) 46-60 (2)
4	Transport (Transport services to end and business customers) Offline and Online Markets (4)	Male (3) Female (1)	21-35 (1) 36-45 (1) 46-60 (1) Above 60 (1)
4	Informal Education (Educational Services) Offline and Online Markets (4)	Male (1) Female (3)	21-35 (1) 36-45 (1) 46-60 (2)

Number of interviewed individuals	Business sector and market type	Profile of interviewed individuals (gender)	Profile of interviewed individuals (age)
3	Healthcare (Health Services) Offline Market (3)	Male (1) Female (2)	36-45 (1) 46-60 (1) Above 60 (1)
3	Sports and Beauty Offline and Online Markets (3)	Male (2) Female (1)	21-35 (2) 36-45 (1)
2	Small Manufacturers and Artisans Offline Market (2)	Male (1) Female (1)	46-60 (1) Above 60 (1)
Total		35 individuals	35 individuals

The collected information was processed using the content analysis method and systematized in a textual format.

RESEARCH RESULTS

The information collected from the in-depth interviews, and processed through content analysis, provides a basis for drawing conclusions that highlight specific aspects of the use and perception of various payment methods and payment innovations. All managers of small businesses have declared that they accept cash payments in their business. They found that cash is the most popular and preferred payment method by their customers (who are primarily Bulgarian citizens). They also consider this method to be the cheapest payment option for their business. However, this does not mean that they are limited to just one payment method. Nearly two-thirds of the interviewed managers shared that they accept two or more different forms of payment. After cash payments, the most popular are payments with credit and debit cards. All interviewees who declared that they use two or more forms of payment stated that they accept card payments. The most frequently mentioned reason for offering this type of payment service is increased demand from customers. Convenience and relatively easy handling are positioned in second place.

When asked what the ratio is between digital payments and cash payments, different results were obtained depending on the type of business, the turnover of the enterprise, the location and the age of the entrepreneur. For example, in hospitality and catering, the share of non-cash payments is growing, mainly with regard to credit and debit cards. At the same time, in retail trade and

transport services, cash payments have a predominant share. There is an opinion that the use of innovative payment methods grows with the increase in the commercial turnover of enterprises. Younger managers are more inclined to take on the challenge of adding new payment methods.

The location of the business is also important for the selection of payment methods offered by small enterprises. In commercial establishments and businesses in large cities, innovative forms of payment are more often applied. In smaller settlements, cash payments prevail, with the exception of tourist sites.

In terms of the age profile of business owners, it is striking that younger entrepreneurs (up to 45 years old) offer innovative forms of payment to their clients significantly more often. At the same time, cash payments prevail among business owners in the age group of over 60. This is, of course, related to the younger generation's better perception of technological innovations, the lower level of digital literacy of older entrepreneurs and the different perception of the risks associated with implementing innovative payment methods.

A factor that influences the entrepreneurs' choice to use innovative forms of payments is their compatibility with other automated systems used in the business – primarily accounting software and inventory reporting systems. Business owners prefer to have the payment and other automated systems serviced by a local provider, since they believe that they respond more quickly and adequately to difficulties and problems that arise.

When asked what the impact of the global pandemic has been on the choice of payment methods, the answers from the conducted interviews show that it has largely changed the attitude of entrepreneurs towards alternative forms of payment. During this period, many of them preferred to offer their customers payment through online channels for the first time, and those who had already adopted such channels are registering an increase in turnover.

Most managers from small businesses who took part in the survey noticed that, when using credit cards, buyers tend to spend larger amounts than if they were buying in cash. They make this conclusion based on an analysis of the average purchase value paid in cash versus that paid by card.

The cost of investing in the technical equipment necessary to make payments is not mentioned as a serious problem. According to the interviewed individuals, the main problem they point out is the high fees charged by banks for processing transactions. More than half of those interviewed describe the fees as too high and label them as a significant cost. This is one of the reasons why, all other things being equal, entrepreneurs prefer paying in cash.

Nearly a quarter of the entrepreneurs who offer card payments complain about frequent failures in the payment system, which hinder and slow down

the processing of transactions. A small part of the interviewed individuals points out a problem with the slow processing of transactions – from the time of making a payment to the moment when the funds actually enter the account. Despite the high fees and potential technical problems, none of the owners plan to stop using alternative methods of cash payment. They would not allow themselves this “luxury”, in their words, due to the competitive pressure and the fear of losing customers.

None of the interviewed individuals were among those who accept cryptocurrencies for payments. The use of crypto assets is still unpopular due to their high volatility, and because it involves intermediaries in the payment process, which are associated with higher costs, uncertainty and increased risk.

When it comes to using artificial intelligence in their daily business and financial activities, most entrepreneurs are interested and would use it in the future if they were convinced of its effectiveness. However, they admit that they are not fully familiar with its capabilities and areas of application.

There is no shortage of concerns about the insufficient level of financial and digital literacy among entrepreneurs. One in five of the survey participants admit that their level of digital knowledge and skills is not at the required level, and they feel afraid or uncertain about introducing innovative forms of payment.

It can be summarized that innovative forms of payment are making their way relatively quickly into the small business sector. The main drivers of this process are the demand for such payment services and the high degree of competition among the businesses that operate them.

CONCLUSION

The rapid development of payment systems is conditioned by the invasion of digital financial services. The implementation of innovative forms of payment by small businesses is crucial not only for the development of their business, but also because it is becoming a matter of survival in an increasingly competitive environment. The study of the drivers and obstacles to the use of payment innovations has clearly shown the benefits of their implementation. The main motivators for the implementation of innovative payments are the requirements and claims of customers, as well as competitive pressure. Next in line are the speed, convenience, and cost-effectiveness of the transactions performed.

The results of the conducted research show the presence of both objective and subjective barriers to the development of innovative payments for small businesses. Business owners' concerns are mainly related to high service

fees, underdeveloped infrastructure, and the risks of cyberattacks and system breaches. Some subjective factors, such as a low level of financial and digital literacy, both among business owners and some of their customers, also act as barriers to the development of innovative payments. Based on the analysis of the objective and subjective limitations to the implementation of innovative payments by small businesses, and with the aim of improving their capabilities, the following recommendations can be made:

- State support is needed for costly investments in infrastructure that do not have a quick return, but are vital for the development and competitiveness of small businesses.
- Legal regulations are needed that encourage innovation and, together with the private sector, build an infrastructure with stable and secure digital networks in remote areas.
- The state and local administration should identify measures to increase financial and digital literacy – organize free training and online courses. The subject of these trainings can be the acquisition of basic knowledge about financial services, investment principles, possible risks and threats in the digital environment, etc.

In order to increase the attractiveness of innovative payments, it takes some time for innovations in payment systems to reach such a critical mass and high level of development, which will have a positive impact on trust in them and on their acceptance by entrepreneurs and their customers.

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PERCEIVED THREATS TO COMPLIANCE WITH THE PRINCIPLES OF ACCOUNTING ETHICS AND EXTERNAL FACTORS FOR UNETHICAL BEHAVIOUR

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Professional accountants in business play an important role in financial reporting quality. Their ethical behaviour is crucial due to their ultimate task - the preparation of financial statements. Since internal and external users of accounting information base their decisions on the financial statements, and the work of accountants is reflected in these reports, the financial statements should be prepared in the public interest. Therefore, financial statements should contain information that is understandable, complete, relevant, unbiased, timely and accurate. Providing trustworthy accounting information is not an easy job. Ethical dilemmas arise from various situations that professional accountants face in their daily work. A challenging circumstance can create pressure that jeopardises compliance with the accounting ethics principles. The research objective is twofold: to examine the impact of unethical behaviour and exposure to threats, and to identify remedial actions that can improve the ethical behaviour of professional accountants. This study examines the relationship between perceived threats to compliance with the fundamental principles (integrity, objectivity, professional competence and due care, confidentiality and professional behaviour) and the extrinsic factors for unethical behaviour of professional accountants. Empirical research is based on an online questionnaire completed by 374 professional accountants in Croatia. The primary data collected as part of the survey were statistically analysed using the IBM SPSS software. The results indicate that insufficient support from the colleagues and the organization to act ethically,

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and a lack of support from professional associations, are related to the threat of self-interest, self-review, advocacy, familiarity and intimidation. On the other hand, conversance with the International Code of Ethics for Professional Accountants leads to ethical behaviour with many positive effects, such as reducing corruption and fraud, reducing pressure on the accountants, increasing their impartiality, reducing conflicts of interest, increasing the credibility of financial statements and maintaining the confidentiality of information.

Key words: *accounting ethics, financial reporting quality, threats, unethical behaviour*

JEL classification: *M41*

INTRODUCTION

As Smith et al. (2009) pointed out, “ethics provides the boundaries by which people relate to the world, including how they do business, treat other people and care for the environment”. Ziedi and Feki (2011) stated that ethics is a social necessity in any relationship and without business ethics, no profession can have its continuity. Business ethics, and in particular, accounting ethics, became an essential topic of academic investigations globally due to the revealed accounting frauds and financial scandals. Unethical behaviour in business practice is on the rise (Messikomer & Cirka; 2010). Frémeaux and Noël (2015) concluded that both individual ethics and organizational ethics are important in the business environment.

Professional accountants in business have a significant role in outlining the financial reporting quality. Their ethical behaviour is crucial because their final task is the preparation of financial statements. Since internal and external users of accounting information make their decisions based on financial statements, the work of accountants reflects on those reports that should be prepared in public interest and, therefore, contain high-quality accounting information (accurate, unbiased, timely, understandable, complete and, therefore, relevant). Providing truthful and reliable accounting information is a heavy task, as accountants may encounter many ethical dilemmas. Some situations might create pressure that creates a threat to compliance with the accounting ethics principles (integrity, objectivity, professional competence and due care, confidentiality and professional behaviour). Pressures to breach accounting ethics principles are categorised as the following: conflicts of interest, influence on the

preparation and/or presentation of information, performing without sufficient expertise or due care, financial interest, inducements, non-compliance with the laws and regulations, and the level of fees. The IESBA (International Ethics Standard Board for Accountants) Code of Ethics differentiates five types of threats to compliance with the ethical principles in accounting: self-interest, self-review, advocacy, familiarity and intimidation threat. These threats should be carefully studied because they may be the source of the unethical behaviour of accountants. The conclusion of several prior studies (Higgs-Kleyn & Kapelianis, 1999; Valentine et al., 2002; Fu et al., 2011; Davidson & Stevens, 2013) is that the code of ethics should be applied in order to improve ethical behaviour.

Based on the moral decision-making theory, this paper examines the possible reasons for unethical behaviour, focusing on the external factors. In addition, the benefits of applying the International Code of Ethics for Professional Accountants are studied as a possible mode of prevention of unethical behaviour. The aim of the study is twofold: to investigate if there is a relationship between threats to compliance with the fundamental principles of accounting ethics and the perceived reasons of unethical behaviour, and to determine the effect of conversance with the Code of Ethics for Professional Accountants on the perceived advantages of its application. The study fills the gap in the empirical evidence regarding the main causes of unethical behaviour of professional accountants. In addition, this study contributes to the body of knowledge on the advantages of application of the aforementioned Code.

The reminder of the paper is arranged as follows. The background on (un) ethical behaviour of professional accountants is described in the following section. The importance of application of the International Code of Ethics for Professional Accountants is presented next. After the formulation of the hypotheses, the research methodology is elaborated along with the findings, followed by concluding remarks.

MORAL INTUITION, MORAL REASONING AND ETHICAL BEHAVIOUR OF ACCOUNTANTS

Moral intuition and moral reasoning have been recently studied in the business context. As far as decision-making is concerned, moral intuition has a deep influence on prompt reactions. On the other hand, moral reasoning (as conscious and rational processes) occurs in a later phase to provide a 'rationale' or a 'sense' for behaviours and decisions undertaken (Zollo et al., 2017).

As Slovic and Västfjäll (2010) stated, “the natural way to deal with moral issues involving risk is to rely on our intuitive feelings” since intuition comes first and directs the responses, unless humans make an effort to think about it. Human intuition is a reliable source of moral knowledge, as it is an expression of deeper, more general values that lie at the core of people as moral beings (McMahan, 2013:114). Values can be defined as persistent belief that certain ways of conduct (e.g. fairness) or end-states of existence (e.g. equality) are desirable compared to the alternatives. Values are drivers of judgments and actions across particular objects and situations, and beyond immediate goals. According to the moral decision-making theory, moral judgment is also affected by personal values. The theory suggests that “personal values reflect the long-term potential for an individual to form a sufficient moral judgment under a given moral setting or moral frame” (Hobson et al., 2011: 92).

In their literature review, Egorov and Verdorfer (2020) acknowledged that the increase of ethical scandals in business resulted in amplified research on the moral dimension of leadership. They argued that the influence of moral intuition in the leadership process is crucial. Moral intuition supplements the existing common rational deliberation approaches to moral leader development. Since the top management creates the framework of organizational culture and ethical climate as well, the role of leadership in the later context should not be diminished. In their study, Domino et al. (2015) acknowledged the effect that ethical climate has on accountants’ ethical behaviour. If the management sets a good example and provides an ethical framework in the organization, the employees will follow. Barrainkua and Espinosa-Pike (2020) acknowledged that professionalism is put at risk when accountants are employed in organizations that emphasize profit at the expense of their professional values. Abdolmohammadi et al. (2009: 194) compared the study on accounting ethics conducted in 1990 to the repeated study in 2005, and concluded that the new generation of accountants achieved significantly lower ethical reasoning scores. Douglas et al. (2001: 101) indicated that professional accountants are exposed to a combination of incentives and opportunities to commit fraud, and suggested that personal values and codes of conduct are important prevention factors for unethical behaviour. Due to the nature of their job and the wide implications of accounting information in the disclosed financial statements, accountants are highly exposed to ethical dilemmas (Marques and Azevedo-Pereira, 2009). Mirshekary and Carr (2015) explored the effects of exposure to unethical practices on the personal attitudes of accountants in small accounting firms. Their findings indicate that if professional accountants are exposed to a broader range of unethical practices, then they also tend to have an attitude

that finds such practices more acceptable. They concluded that it seems that “dishonest behaviour can be contagious”.

PROFESSIONAL ACCOUNTANTS’ CODE OF ETHICS

Accounting manipulations diminished the faithful representation of accounting information in financial statements, which resulted in low-quality financial reporting. Such events led to the notion of enhancing the importance of setting and applying the corporate codes of conduct and codes of ethics, as well as the International Code of Ethics for Professional Accountants. Professional organizations implemented the code of ethics to promote public trust in the quality of the services delivered by members of the specific profession. The International Code of Ethics for Professional Accountants, established by the International Ethics Standard Board for Accountants (IESBA), represents a comprehensive framework for ethical conduct. IESBA is an independent standard-setting body instituted by the International Accounting Standards Board (IFAC) that develops and issues (in the public interest and under its own authority) the ethics standards for professional accountants that are in use around the globe. In fact, IFAC’s membership encompasses more than 180 professional accountancy organizations in over 135 jurisdictions, representing more than 3 million professional accountants in public practice, industry, government and education (Handbook of the International Code of Ethics for Professional Accountants, 2024).

One of the expected benefits of compliance with a corporate governance code is an improvement in the quality of accounting information provided by companies that should influence managerial practices for managing results (Elage & Mard, 2018). Financial reporting quality can be jeopardized due to unethical behaviour of professional accountants in business. According to the International Code of Ethics for Professional Accountants, accountants include accounting professionals who are employed, engaged or appointed in a managerial or non-managerial capacity in, for example, commerce, industry or services, the public sector, education, not-for-profit organisations, and regulatory or professional bodies. This Code of Ethics promotes the application of fundamental ethical accounting principles to reduce unethical behaviour by accountants, as well as auditors. When faced with various ethical dilemmas, they should consult the International Code of Ethics for Professional Accountants or a similar ethical accounting framework. The Code provides conceptual insights and guidance that should be applied so as to recognize, assess

and address all five types of threats (self-interest threat, self-scrutiny threat, advocacy threat, familiarity threat and intimidation threat). The various circumstances that may threaten the objectivity and independence of accountants and auditors fall into one or more of the above categories. A self-interest threat occurs when a financial or other interest is about to improperly influence an accountant's judgment or behaviour (e.g. receipt of a loan from an employer, access to company assets for personal use, offer of a gift from a supplier, etc.). A professional accountant may be at risk of self-review if he or she does not properly evaluate the results of a previous judgment or activity (of the professional accountant or an employee in the professional accountant's firm or employer) on which he or she could rely in forming a judgment about his or her current activity. If an accountant is able to manipulate information in a prospectus in order to obtain favourable financing, a threat of advocacy may arise. Thus, an advocacy threat exists if the auditor could upkeep the position of a client or organization that employs him/her, which would compromise his/her objectivity. A threat of familiarity arises when an accountant has a close or even long-standing relationship (particularly if a family member is involved) with individuals who have influence over the business decisions. Long-term or close relationships with a client or company can lead to an accountant being overly biased and sympathetic to the client's interests, or overly accepting of their work. A threat of intimidation exists when an accountant or their family members are threatened with dismissal or replacement due to the application of accounting standards or the nature of financial reporting. A threat of intimidation could exist if an accountant is discouraged from acting objectively (due to actual or perceived pressure), including attempts to exert undue influence over the accountant. The Code serves as a means to achieve awareness of ethical dilemmas and threats that might happen.

HYPOTHESES

Prior studies have revealed that the ethical climate and ethical culture affect accountants' behaviour (Douglas et al., 2001; Shafer, 2015). Bravo and Reguera-Alvarado (2017) observed that independent directors have a crucial monitoring role in terms of reinforcing the integrity and credibility of disclosed financial statements. Those who are independent are able to provide greater oversight of the accounting process and support the proliferation of financial reporting quality. On the other hand, professional accountants without support of their employing organisation and professional association might

be facing greater pressures to breach the accounting ethics principles. The findings of Rogošić and Repić (2024) showed that accountants are most often exposed to the pressure to perform without sufficient expertise or due care. Accountants are under high pressure to finish their duties within tight deadlines. In addition, they regularly perform tasks that are not typical for the accounting profession (i.e. registration of new employees and tax consulting). In these cases, accountants might face threats that should not be overlooked, because they may be the source of their unethical behaviour. A prior study (Rogošić, 2021) indicated that, among all five types of threats to compliance with the fundamental principles of accounting ethics, accountants are subject to the intimidation threat the most. According to the previous research results, it is reasonable to assume the following:

H1: The perceived exposure to threats is associated with the external factors of unethical behaviour of professional accountants.

The most renowned framework for the ethical behaviour of accountants is the International Code of Ethics for Professional Accountants, with guidelines that address the issues concerning the threats to compliance with the fundamental accounting principles. This Code is recommended by many scholars (Nerandzic et al., 2012; Espinosa-Pike and Barrainkua-Aroztegi, 2014; Ishaque, 2021), as it can offer insight and solutions for various ethical dilemmas that accountants might come across. Being familiar with the Code could enable more ethical decision-making for accountants, which would lead to many beneficial outcomes. Therefore, the second hypothesis is formulated as follows:

H2: Conversance with the International Code of Ethics for Professional Accountants positively affects the reduction of corruption and fraud, lessening of the accountant's exposure to pressure, increasing the impartiality of accountants, diminishing conflicts of interest, increasing credibility of financial statements, and respecting the confidentiality of information.

METHODOLOGY AND RESULTS

The empirical research instrument used in this study was an online questionnaire. An invitation containing the link to this survey (created using Google Forms) was sent to randomly selected e-mail addresses of accountants in Croatia. After three reminders, 374 professional accountants completed the questionnaire (although not everyone provided answers to all the questions, therefore the number of observations varies). This questionnaire con-

tains closed-ended questions (mostly a 5-point Likert scale) and various demographic questions. The collected primary data were analysed using the MS Excel and IBM – SPSS 23 programs. Univariate statistics was used to validate the hypotheses.

As mentioned before, previous studies have shown the positive effect of organizational ethical context (ethical climate and ethical culture) on accountants’ behaviour, but there was no empirical evidence on how the other external factors affect (un)ethical behaviour. Descriptive analysis indicates that inadequate management and unethical organizational climate seem to be the main reason for the unethical behaviour of professional accountants in business (the mean value is 3.8049). A lack of support from the colleagues and the organization to act ethically (the mean value is 3.4973) was also observed as an important cause of unethical behaviour of professional accountants. Lacking the support from professional bodies such as associations of accountants (the mean value is 3.0405) can also affect this type of professional behaviour. In order to validate the first hypothesis, the Jonckheere-Terpstra test was performed (Table 1, Table 2, Table 3, Table 4 and Table 5).

Table 1: Perceived exposure to the self-interest threat and external factors of unethical behaviour

	No support from colleagues and organisation	No support from professional associations
Number of Levels in Self-interest threat	5	5
N	368	368
Observed J-T Statistic	27041	29221.5
Mean J-T Statistic	23950.5	23950.5
Std. Deviation of J-T Statistic	1078.689	1088.367
Std. J-T Statistic	2.865	4.843
Asymp. Sig. (2-tailed)	0.004	0.000
a. Grouping Variable: Self-interest threat		

Source: Author’s calculation

Table 2: Perceived exposure to the self-review threat and external factors of unethical behaviour

	No support from colleagues and organisation	No support from professional associations
Number of Levels in Self-review threat	5	5
N	367	367
Observed J-T Statistic	26208	30461
Mean J-T Statistic	24639.5	24639.5
Std. Deviation of J-T Statistic	1087.902	1097.896
Std. J-T Statistic	1.442	5.302
Asymp. Sig. (2-tailed)	0.149	0.000
a. Grouping Variable: Self-review threat		

Source: Author's calculation

Table 3: Perceived exposure to the advocacy threat and external factors of unethical behaviour

	No support from colleagues and organisation	No support from professional associations
Number of Levels in Advocacy threat	5	5
N	369	369
Observed J-T Statistic	28834.5	29647
Mean J-T Statistic	25015.5	25015.5
Std. Deviation of J-T Statistic	1096.923	1106.727
Std. J-T Statistic	3.482	4.185
Asymp. Sig. (2-tailed)	0.000	0.000
a. Grouping Variable: Advocacy threat		

Source: Author's calculation

Table 4: Perceived exposure to the familiarity threat and external factors of unethical behaviour

	No support from colleagues and organisation	No support from professional associations
Number of Levels in Familiarity threat	5	5
N	369	369
Observed J-T Statistic	26993	29034
Mean J-T Statistic	24624.5	24624.5
Std. Deviation of J-T Statistic	1090.84	1100.589
Std. J-T Statistic	2.171	4.006
Asymp. Sig. (2-tailed)	0.030	0.000
a. Grouping Variable: Familiarity threat		

Source: Author's calculation

Table 5: Perceived exposure to the intimidation threat and external factors of unethical behaviour

	No support from colleagues and organisation	No support from professional associations
Number of Levels in Intimidation threat	5	5
N	367	367
Observed J-T Statistic	28023	28707
Mean J-T Statistic	25384.5	25384.5
Std. Deviation of J-T Statistic	1095.409	1104.906
Std. J-T Statistic	2.409	3.007
Asymp. Sig. (2-tailed)	0.016	0.003
a. Grouping Variable: Intimidation threat		

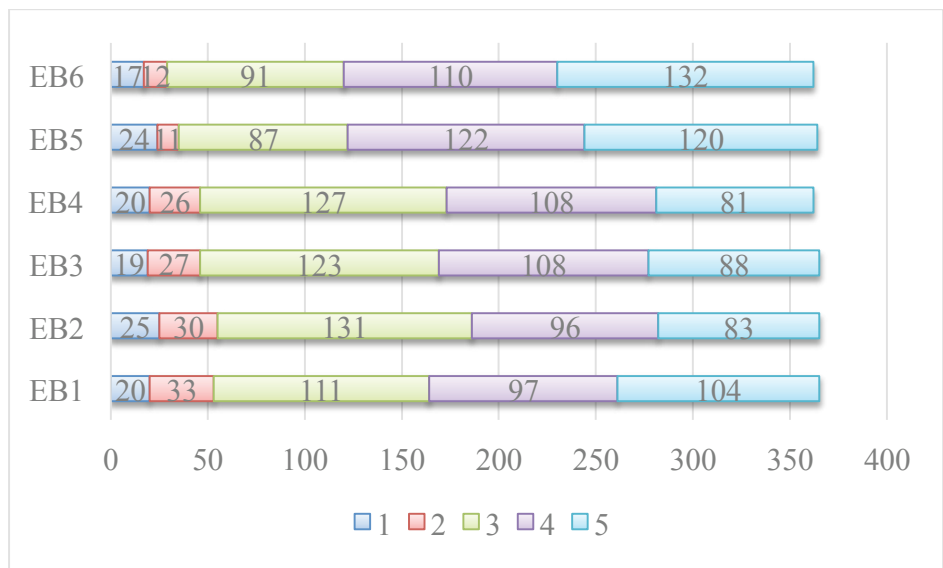
Source: Author's calculation

An in-depth analysis of the relationship of all five threats to compliance with the accounting ethics principles and external factors indicates that perceived threats are related to a lack of support from the colleagues, the organisation, and professional associations to act ethically. Only the level of perceived self-review threat is not related to the degree of a lack of support from colleagues and organisation. Self-review threat occurs when a professional accountant does not make an adequate evaluation of the results of a previous judgment made or activity performed (by the accountant or by another

individual within the accountant’s firm or employing organization), on which the accountant might rely when forming a judgment that reflects on their current activity. Therefore, an accountant who perceives a lack of support from the colleagues and the employing organisation to act ethically is more careful when evaluating actions and judgements of their colleagues.

In order to mitigate unethical behaviour, accountants should be familiar with the Code. Seeking guidance from the Code, along with the innate moral intuition and moral reasoning, can enable moral decision-making with many beneficent outcomes. Application of the accounting ethics code positively affects the reduction of corruption and fraud (EB1), lessening of the accountant’s exposure to pressure (EB2), increasing the impartiality of accountants (EB3), diminishing of conflicts of interest (EB4), increased credibility of financial statements (EB5), and respecting the confidentiality of information (EB6).

Graph 1: The positive outcomes of the application of the Code



Source: Author’s calculation

According to the results shown in Graph 1, most of the respondents (132 accountants) strongly agree that respecting the confidentiality of information (EB6) is the most noticeable benefit of the code application, followed by increased credibility of financial statements (EB5). On the other hand, they believe that lessening the accountants’ exposure to pressure (EB2) is the least

positive outcome of the application of the International Code of Ethics for Professional Accountants.

The second hypothesis was tested using the same univariate statistics tool (the Jonckheere-Terpstra test). The results are presented in Table 6.

Table 6: Conversance with the Code and beneficial outcomes of ethical behaviour

	EB1	EB2	EB3	EB4	EB5	EB6
Number of Levels in Conversance with the Code	5	5	5	5	5	5
N	364	364	364	361	363	361
Observed J-T Statistic	30.652.500	30.026.500	30.269.500	29.062.000	30.260.000	30.577.500
Mean J-T Statistic	24.669.500	24.669.500	24.669.500	24.279.500	24.532.000	24.265.500
Std. Deviation of J-T Statistic	1.076.399	1.073.102	1.072.329	1.057.541	1.062.742	1.050.883
Std. J-T Statistic	5.558	4.992	5.222	4.522	5.390	6.006
Asymp. Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000

a. Grouping Variable: Conversance with the Code

Source: Author's calculation

The findings (Table 6) indicate that conversance with the Code enhances the application of its guidelines. This has various positive effects for the organization and the society in general, such as improved financial reporting quality (credibility of financial statements), enhanced confidentiality of accounting information, reduced corruption and fraud, lower accountants' exposure to pressure, increased impartiality of accountants, and reduced conflicts of interest. Being familiar with the Code makes accountants more ethically aware and alert. This leads to their better (moral) judgement and makes their professional behaviour more ethical. Thus, one of the remedies for unethical behaviour of accountants is taking time to read the Code and reflect on the consequences of their actions.

CONCLUDING REMARKS

Attaining complete professional independence never comes without obstacles in the accounting profession. Sometimes accountants find themselves in ethically questionable situations, circumstances and situations that create threats to compliance with the accounting ethics principles. Besides intrinsic motives, accountants may face external factors prompting them to act unethically. Prior research showed that (un)ethical climate and (un)ethical culture enable unethical behaviour of employees, including accountants, which was supported in this study. Insufficient support from the colleagues and the employing organization to act ethically and absence of support from professional accounting associations were analysed as additional external factors of unethical behaviour. The frequency of exposure to the five types of threats (self-interest threat, self-review threat, advocacy threat, familiarity threat and intimidation threat) was examined. The findings indicate that accountants who perceive frequent exposure to the threats also admit that insufficient support from their colleagues, the employing organization and accounting associations can cause them to act unethically. In order to reduce unethical behaviour, accountants are advised to consult the International Code of Ethics for Professional Accountants. The contribution of this study is also in the inclusion of the positive effects of the application of the Code. The more familiar accountants are with the Code, the more positive are the effects expected from its application. According to the respondents, the most important effects include greater confidentiality of information and increased credibility of financial statements (financial reporting quality).

The limitation of this study lies in the fact that it did not include the intrinsic motivation factors for unethical behaviour of accountants. Future research should encompass those intrinsic factors in order to provide a better understanding of what makes accountants act unethically.

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THE FLIP SIDE OF THE GREEN TRANSITION: PREVALENCE OF DIRTY JOBS IN THE CROATIAN ECONOMY

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The EU-wide green transition policy initiative advocates for significant changes across the EU economies. This ambitious process is expected to have a substantial effect on the labour markets, primarily through significant creation of green jobs and reduction of the share of pollution-intensive jobs. The existing literature makes considerable efforts to define the concept of green jobs and to devise a sound methodological framework for estimating the size of green employment. However, reaching a consensus remains elusive. At the same time, relatively less attention is paid to estimating the share of high-polluting jobs. A decrease of such jobs would potentially have a disruptive effect on certain segments of the labour market. While Croatia has adopted the same green transition policy framework, empirical research on this topic is scarce. The present paper aims to fill this gap by providing estimates of the prevalence of high-polluting jobs, based on a methodological approach that allows for a comparison with other EU countries. Using comprehensive data on emissions and employment by industry, along with individual-level EU Labour Force Survey data for the period 2002–2022, and relying on a recently proposed methodology, we estimate the share of high-polluting jobs in Croatia. Our results suggest that Croatia maintains an average position among the EU economies. The average characteristics of job holders in

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high-polluting industries in Croatia closely resemble those in other EU countries. Furthermore, our findings indicate no significant changes in the share of high-polluting jobs in Croatia during the analysed period. This suggests that significant policy measures are still required to ensure successful greening of the Croatian economy and, consequently, the labour market. By highlighting these aspects, this study aims to contribute to a broader understanding of the impacts of green transition policies on labour markets, and to support the formulation of effective strategies for a sustainable future.

Keywords: *Green transition, high-polluting jobs, labour market, Croatia*

JEL classification: *J24, Q52, Q58*

INTRODUCTION

The necessity of transforming our societies in order to protect the environment has been widely discussed in the public. While there is a general approval of the process, it is relatively less clear what it entails. The United Nations Environment Programme (UNEP, 2011) suggests a broad definition, stating that it implies enhancing well-being and social equity while reducing environmental risks. Regardless of the blurry overall definition and the lack of clear targets, the process is supported by various policies and measures, including Europe's 2020 strategy (European Commission, 2010). As the discussions on the green transition advanced, policymakers became increasingly concerned about its impact on labour markets. This is particularly pertinent for workers in polluting industries, who might face job losses or skill obsolescence (Chateau, Bibas & Lanzi, 2018). While new job opportunities are likely to emerge, for example in the renewable energy sector, some existing jobs may be lost.

Because of these transforming effects, the concept of greening the labour market is gaining traction at the policy level (Urban et al., 2023), with countries developing dedicated strategies either to support job creation in the green sectors or to alleviate difficulties in high-polluting sectors. These activities are aligned with traditional environmental policy agendas, generally divided into “brown” topics focused on pollution prevention and control, and “green” topics focused on natural resources and ecosystems (Agyeman, 2008; Jamison, 2003). While previous studies have been more oriented on the assessment of pollution prevention and control measures for the enterprises (Feng et al.,

2023), less evidence is available on the possible effects on the workers (Wang, Hu & Lin, 2021).

Assessing the effect on the labour market requires an understanding of the environmental impacts of jobs. To that end, research has been primarily focused on the precise identification of green jobs and estimates of their share in the economy. Currently, the evidence implies that the share is relatively low (Chateau, Bibas & Lanzi, 2018). Less attention is given to the destruction of the “brown” sector. However, from the policy perspective, it is crucial to assess the risk of job loss for different worker categories and to devise measures to improve their re-employment prospects. Identifying vulnerable workers and providing targeted support is essential for reducing the overall societal burden of the green transition.

The existing evidence for Croatia is limited, with only two studies providing estimates for Croatia, both placing it among the countries with an above-average share of brown jobs (Tyros, Andrews & de Serres, 2023; Vandeplas et al., 2022). This paper aims to complement these findings, first by providing an estimate of the share of high-polluting jobs¹ in the Croatian economy, relying on a recent methodology proposed by Causa, Nguyen & Soldani (2024a), and thus ensuring their comparability with other OECD economies². Second, it seeks to provide a deeper insight into the prevalence of high-polluting jobs in

¹ Throughout the paper, we use the terms “brown jobs”, “high-polluting jobs”, and “dirty jobs” interchangeably. All three refer to jobs that are associated with significant environmental pollution.

² While all three studies – Causa, Nguyen & Soldani (2024a), Tyros, Andrews & de Serres (2023) and Vandeplas et al. (2022) – address the issue of employment in the context of the green transition, only Causa, Soldani & Nguyen (2024a) provide a more direct and quantifiable assessment of high-polluting jobs specific to each country. Tyros, Andrews & de Serres (2023) develop indicators of green skills within labour markets across numerous OECD and non-OECD EU countries. Their methodology allows for the assessment of the composition of green skills within various occupations and the potential for workers in brown (high-polluting) jobs to transition to green jobs. The study emphasizes the alignment of skill sets between brown and green occupations, suggesting that many workers in brown jobs possess the necessary skills to move into green roles, though exceptions exist, particularly in production-related occupations. On the other hand, Vandeplas et al. (2022) examine the potential employment impacts of the green transition within the EU. The authors categorize jobs into three types: green, white, and brown. Brown jobs are identified as those likely to be negatively affected by the green transition due to their association with high pollution levels. Vandeplas et al. (2022) provide insights into the sectors and regions that may be most impacted, and their focus is on the broader implications and necessary policy responses.

Croatia by exploring the trends in the share of high-polluting jobs and exploring the key characteristics of employees in these occupations.

The paper adopts the following structure. The next section briefly summarizes the literature. After that, we present the methodology and data, followed by the results and discussion. The last section summarizes the conclusions.

LITERATURE REVIEW

Evidence of climate change has led many countries to emphasize the need for a faster decarbonization of their economies. In the context of the EU, the European Green Deal has been adopted, advocating for a comprehensive transformation of the EU area from an economy reliant on fossil fuels and environmentally harmful practices to the one that prioritizes carbon neutrality (European Commission, 2019). The green transition is expected to drive a technological transformation where brown sectors will either disappear or be transformed through cleaner technologies. This transformation is naturally occurring across different EU countries to varying extents. Countries with a higher prevalence of high-polluting industries are expected to face challenges, while others may see new business opportunities emerging. Structural changes resulting from the green transition are anticipated to significantly impact the labour markets, creating both opportunities and challenges in various sectors (Bowen, Kuralbayeva & Tipoe, 2018).

From a policy perspective, identifying spatial differences in the prevalence of brown jobs is particularly important, as this can highlight areas with increased risks of higher numbers of workers facing dismissal (Song et al., 2021). In these areas, active policy measures aimed at increasing the availability of upskilling and reskilling programs could be beneficial in alleviating the potentially adverse effects of the green transition on local labour markets.

The innovation activity is imminent to the green transition, as new products and production processes are expected to be developed to offer solutions to the pollution problems. While it is not always clear whether technological advancements will lead to new job creation, the literature frequently suggests that innovation activity is likely to create demand for new skills (Horbach & Rammer, 2022). Thus, labour market transformations related to the green transition are well-embedded in the discussions of skill-biased technological change literature (Machin, 2001). However, understanding the specific labour market changes resulting from the green transition requires pinpointing occupational changes. In this respect, greening the labour market is related to

the discussions on the effects of automation and digital jobs (Autor, Levy & Murnane, 2003) on skill demand.

In order to analyse these changes and devise specific policy measures, it is first necessary to define the concepts of green and high-polluting jobs. Urban et al. (2023) provide a comprehensive discussion on developing various concepts related to the precise identification of green jobs. One of the most influential definitions is proposed by UNEP (UNEP/ILO/IOE/ITUC, 2008), defining green jobs as decent jobs in any economic sector that contribute to preserving, restoring, and enhancing environmental quality through (i) the production of environmental outputs (goods and services – output-based) or (ii) the use of environmentally friendly technologies in production (process-based).

This definition has inspired two main approaches to estimating the shares of green and high-polluting jobs in an economy. The *output-based* concept focuses on the products and services produced by an industry, and their environmental impact (ILO, 2013). In this case, if an industry's final product is associated with environmental benefits, jobs in that industry are considered green. The *process-based* concept evaluates whether processes and practices within the industry meet certain environmental standards. Thus, jobs in an industry with sustainable production processes can be considered green. Both approaches yield only very broad categories of industries and can be criticized on the grounds that each industry can (and usually does) contain both green and brown jobs.

Following the literature on the effects of automation and other types of technological changes on labour demand (Acemoglu & Restrepo, 2019), a task-based approach has emerged as more convenient for identifying specific occupations as green or brown. This approach enables understanding the changes in occupation and skill requirements associated with transitions to a greener economy (Elliott et al., 2021). The essence of this approach is that each occupation can be viewed as a bundle of tasks. Some tasks can be labelled green if they are associated with improving environmental sustainability or reducing greenhouse gas emissions (Vona et al., 2018). The task content of each occupation follows the O*NET taxonomy devised for the United States (Dierdorff et al., 2009). The task-based approach is also proposed to identify brown jobs (Vona et al., 2018). The estimates in the present paper rely on a recent variant of this methodological outline.

Empirical estimates, predominantly focused on advanced economies, have identified a relatively low share of green jobs (Bluedorn et al., 2023; Causa, Soldani & Nguyen, 2024a). Winkler-Seales et al. (2024) introduce a novel dataset to assess green occupations and sectors across countries at different

stages of economic development. Using the O*NET, the study classifies green jobs based on their environmental impact and finds a strong positive correlation between the share of green jobs and GDP per capita. Similarly, Alexander et al. (2024) employ a task-based framework to examine the labour market implications of the green transition, with a particular focus on gender disparities. Their findings highlight that while the green transition presents new employment opportunities, men are more likely to be employed in green jobs than women due to occupational segregation.

Bassi & Guidolin (2021) investigate green employment in European small and medium enterprises (SMEs) using the Eurobarometer survey data. They find that firms with dedicated green jobs are more likely to implement resource efficiency practices, establishing a link between green employment and environmental performance. The ILO (2018) uses economic modelling to project job creation under different green transition scenarios, estimating that the shift to a greener economy could generate 24 million jobs globally by 2030, counterbalancing employment losses in traditional high-polluting industries.

Studies further suggest that both green and high-polluting jobs in the US and EU countries tend to be concentrated across several categories: industries (Scholl, Turban & Gall, 2023), sex (Bluedorn et al., 2023; Causa, Soldani & Nguyen, 2024b), skills (Vandeplas et al., 2022), educational attainment (Causa, Soldani & Nguyen, 2024b), and rural areas (Causa, Soldani & Nguyen, 2024b). These estimates provide an initial profile of the population most vulnerable to the adverse effects of the green transition. The remainder of this paper is devoted to exploring how Croatian data depicts the local landscape of high-polluting jobs.

METHODOLOGY AND DATA

We use the methodology proposed by Causa, Soldani & Nguyen (2024a) who developed a framework for identifying high-polluting jobs across European countries. It overcomes the limitations of relying on US-centric classifications and introduces adaptations to accommodate the specific characteristics of the European data and emission patterns.

IDENTIFYING HIGH-POLLUTING JOBS

The identification of high-polluting jobs is based on their association with high-polluting industries. It proceeds in two steps: (1) the identification of

high-polluting industries; (2) the identification of high-polluting occupations within these industries.

IDENTIFYING HIGH-POLLUTING INDUSTRIES

In order to evaluate whether an industry is high-polluting, we rely on emissions intensity, which is defined as the amount of pollutant emissions per worker and calculated based on industry-level emissions and employment data. The following pollutants are considered: carbon monoxide, carbon dioxide, nitrogen oxides, particulate matter smaller than 10 μm , particulate matter smaller than 2.5 μm , sulphur dioxide, and non-methane volatile organic compounds³.

The industries are ranked by their emissions per worker for each of these pollutants. An industry is classified as high-polluting if its emissions per worker exceed the 85th percentile of the emissions intensity distribution for at least three of the seven pollutants. In order to smooth the year-to-year fluctuations and mitigate the influence of outliers, Causa, Soldani & Nguyen (2024a) calculated the emissions intensity as the average emissions per worker over the period 2011–2019, which corresponds to the period considered in their analysis. By adopting the same methodology as Causa et al. (2024a), we can make reliable comparisons between Croatian figures (which we calculate) and the figures from other European countries (as computed in Causa et al. (2024a)).

IDENTIFYING HIGH-POLLUTING OCCUPATIONS

The identification of high-polluting occupations within high-polluting industries is based on the employment distribution of occupations across industries. The distribution of occupations within industries is derived from the detailed UK 2011 Census, which provides a bivariate distribution of occupations (at the SOC 4-digit level) and industries (at the SIC 2-digit level). These distributions are then cross-walked to European occupational classification (at the ISCO 4-digit level) through an official crosswalk from the UK Office for National Statistics (ONS). An occupation is considered high-polluting if the

³ These pollutants are selected due to their widespread environmental impact, both in terms of climate change and public health.

share of workers with this occupation in high-polluting industries is at least seven times larger than this share averaged across all occupations⁴.

Aligning the UK and European occupational classifications is necessary because the analysis is conducted using the European Labour Force Survey (EU-LFS) data which provides employment distribution across European countries by occupations. In order to align this occupational classification with the EU-LFS data, further aggregation is required in which the ISCO 4-digit classifications are aggregated into ISCO 3-digit groups, with each ISCO 3-digit occupation being assigned a fractional score⁵. This score reflects the proportion of high-emission 4-digit occupations which are contained in each 3-digit occupation. The score ranges from 1, if all underlying 4-digit occupations are high-emission, to 0 if none are.

Causa, Soldani & Nguyen (2024a) approach the results in a country-specific list of high-polluting occupations compatible with EU-LFS data. It enables cross-country comparisons and highlights the occupations disproportionately impacted by high-emission industries. While the methodology effectively integrates diverse datasets, it assumes that occupational distributions in the UK 2011 Census are broadly representative of other European countries, which may not always hold true due to variations in national industrial compositions. Despite these challenges, the framework offers an advancement in identifying high-polluting occupations within the European context.

DATA

We use the emission data from Eurostat's Air Emissions Accounts⁶ and employment data from Eurostat's National Accounts⁷ for estimating the emissions per worker over the period 2011–2019, as proposed by Causa, Soldani & Nguyen (2024a).

In order to identify the distribution of occupations by industry, the UK 2011 Census⁸ is used. Finally, we use the Croatian component of the EU-LFS

⁴ Since some occupations are more concentrated in high-polluting industries than others, this measure helps to isolate those occupations that are most closely associated with high-polluting industries.

⁵ Such aggregation is necessary since the EU-LFS classifies occupations at the ISCO 3-digit level for the majority of the countries in the sample.

⁶ https://ec.europa.eu/eurostat/databrowser/view/env_ac_ainah_r2/default/table?lang=en.

⁷ https://ec.europa.eu/eurostat/databrowser/view/nama_10_a64_e/default/table?lang=en.

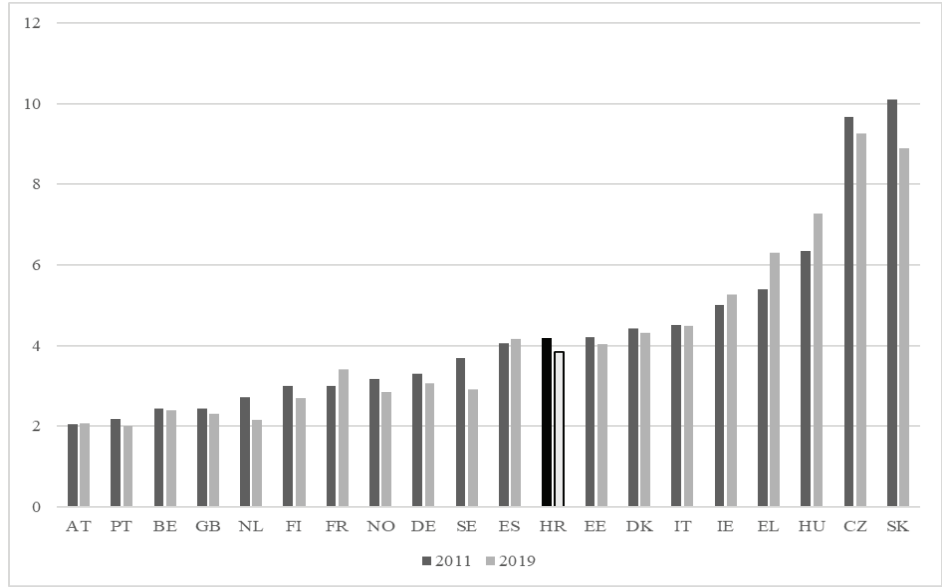
⁸ <https://www.ons.gov.uk/census/2011census>.

spanning the period 2002–2022 in order to calculate the size of employment in high-polluting jobs in Croatia. The EU-LFS⁹ also provides data on several personal and job characteristics that we use to explore the heterogeneity of high-polluting jobs across these characteristics.

RESULTS AND DISCUSSION

We start by comparing the share of high-polluting jobs in Croatia with other countries. The results are presented in Figure 1.

Figure 1: Country comparison of high-polluting jobs as a percentage of total employment



Source: Own estimates

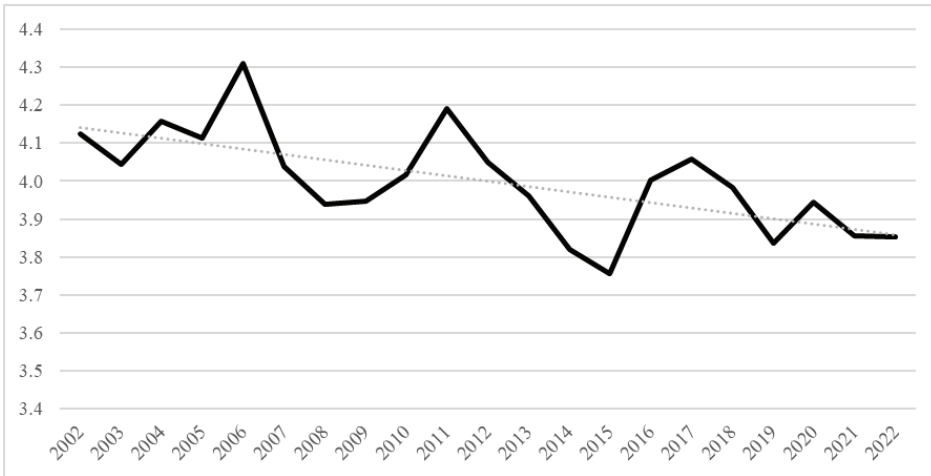
According to our estimates, Croatia does not show a high share of high-polluting jobs compared to other countries. Furthermore, our estimate of around 4 percent places Croatia in the middle of the distribution of other European countries, and is significantly lower than the estimates reported in previous

⁹ <https://ec.europa.eu/eurostat/web/microdata/european-union-labour-force-survey>.

studies. For example, Tyros, Andrews & de Serres (2023) estimated for Croatia an 8 percent share for the 2017–2019 period, while Vandeplas et al. (2022) suggested an even higher estimate of around 12 percent in 2021. Interestingly, both of these studies place Croatia among the top five countries with the highest share of brown jobs, but identify different countries with higher shares than Croatia. Since all of the studies follow the same general methodological outline suggested by Vona et al. (2018), the range of the estimated shares of high-polluting jobs in Croatia is somewhat puzzling. It suggests that (i) data availability on emissions, influencing the categorization of an industry as high-polluting, (ii) differences in the identification of specific jobs as high-polluting depending on data availability and crosswalk applications, and (iii) aggregation depending on the classifications applied, strongly influence the resulting estimated share of high-polluting jobs and result in different country rankings. This clearly indicates that further methodological or data improvements are required in order to ensure more robust findings.

Regardless of the estimated size of the share, the data could indicate the same trend. However, here we also find some differences from previous estimates. As can be observed from the data presented in Figure 2, our estimates indicate a relatively small decrease in the share of high-polluting jobs in the 2002–2022 period. Contrary to our findings, Vandeplas et al. (2022) report a significant decline between 2008 and 2021, from 16 percent to around 12 percent. Future research efforts should be devoted to methodological or data improvements that would result in more consensual evidence.

Figure 2: High-polluting jobs as a percentage of total employment in Croatia, 2002-2022



Note: The dotted grey line depicts the linear time trend

Source: Own estimates

The comparison shows that average workers in high-polluting jobs in Croatia do not possess the specific characteristics that would differentiate them from average workers in similar occupations in other countries¹⁰. For example, Croatian data reveals that women (1.2 percent of the total female employment, compared to 6 percent for men in 2019) are less frequently present in brown occupations. This is because women are more likely to work in the service sector, and men are more likely to occupy jobs in manufacturing. Our results corroborate the findings by Vandeplas et al. (2022), who suggested that the green transition is likely to disproportionately affect the medium-skilled male population, that is already at a higher risk of job losses due to the digital transition and the automatization processes. This does not imply that female workers are not under pressure of losing their jobs due to the de-routinization of the work process, however, they are less likely to face the double jeopardy.

The data further suggests that Croatian employees with high educational attainment are less frequently employed in high-polluting jobs (1.2 percent of the total employment), than those with lower and medium level educational

¹⁰ Detailed comparisons are not presented due to space limitations, but are available to be presented by the authors upon request.

attainment (5 percent). This is also consistent with the typical profile of high-polluting manufacturing jobs.

Considering the age structure, the 25–34 age group has the smallest share of persons employed in high-polluting jobs (3.4 percent), while the 56–64 age group has the highest share (4.1 percent)¹¹. This pattern is not uniform across countries, but it can also be observed in Denmark and Ireland. Interestingly, Croatia belongs to a group of countries where differences in shares of high-polluting jobs between different age groups are not high. Denmark and Ireland, on the other hand, have more pronounced differences across age groups. It suggests that specific demographic conditions also play a significant role in the age structure of employment. The data also reveals a lack of significant change in the age structure of high-polluting jobs in Croatia during the period 2002–2022. Thus, regardless of the declarative support for the environment attributable to younger generations in public discourse (Ivanović, Puđak & Trako Poljak, 2022), it seems that when it comes to employment, their choices might be guided by more pragmatic reasoning.

Studies in other countries have already documented an uneven geographical distribution of the green transition process, aggravating the skills mismatch on the labour market. For example, in the context of the US renewable energy sector, Curtis & Marinescu (2023) warn that new (green) jobs are not created in the same areas where brown jobs are destroyed, leading to potential regional labour market disruptions.

Studies conducted for European countries also confirm these patterns. Consoli et al. (2016) find that the green transition favours workers with higher cognitive and technical skills, potentially widening the regional inequalities. Causa et al. (2024c) argue that climate change mitigation policies affect the allocation of workers in the labour market, with jobs in high-polluting industries contracting and jobs in low-polluting industries expanding, leading to regional disparities. These findings suggest that without targeted policies to support reskilling and job mobility, the transition to a greener economy could exacerbate the existing regional and occupational disparities.

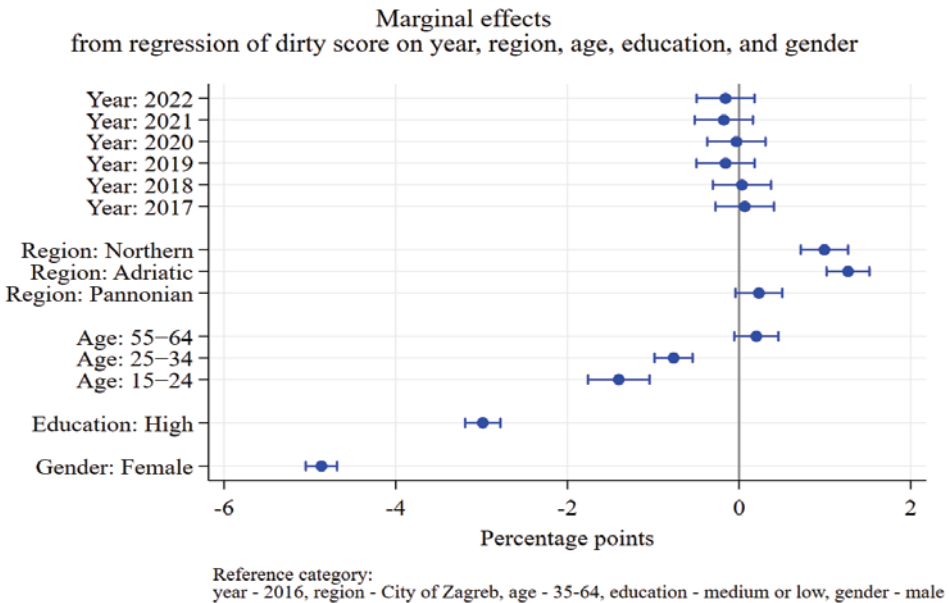
On the other hand, Croatian data shows that, unlike some other countries, high-polluting jobs are not specifically concentrated in rural areas. This might be the consequence of deindustrialization, widespread in many developed countries (Škuflić & Družić, 2016), and strongly present in Croatia during the

¹¹ The comparison of the share of persons employed in high-polluting jobs across age groups is based on our own estimates for Croatia. This figure is not included in the text so as to save space, but it is available to be presented by the authors upon request.

early periods of transition. Subsequently, previous industrial zones have been gradually dissolved and many geographical areas where the manufacturing industry was causing high pollution are not operational.

Focusing on the Croatian data only, we can summarize the marginal effects of year, region, age, education, and gender on the “dirty score”, based on a regression analysis (see Figure 3). The reference category is defined as including the year 2016, the City of Zagreb, individuals aged 35–64, with medium or low education levels, and male. The results indicate that while dirty scores are lower among younger workers (relative to individuals aged 35–64), females and those with more education, they are higher in the Northern and Adriatic regions (relative to the City of Zagreb).

Figure 3: Characteristics of employees in high-polluting jobs in Croatia



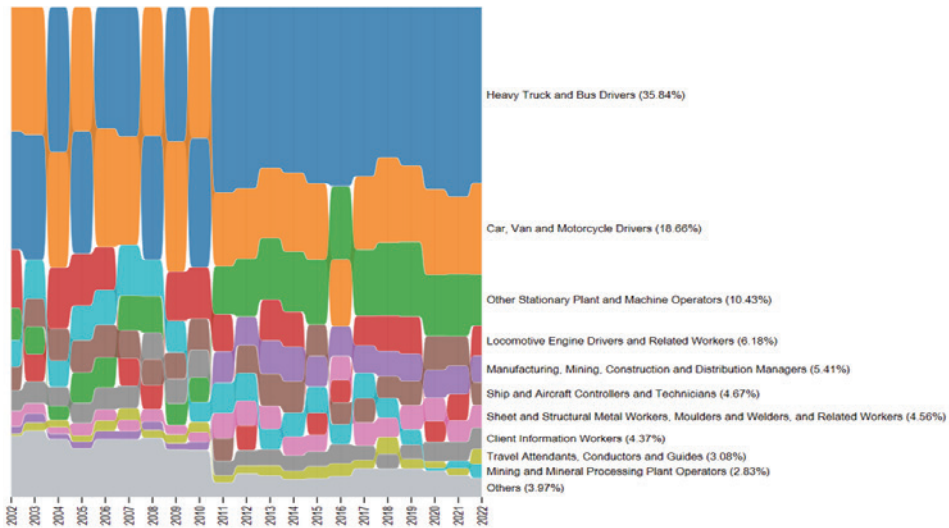
Notes: Based on an OLS regression of the dirty score (see section ‘Methodology and Data’) on year, regional, age, educational, and gender dummies. The marginal effect of a variable is calculated as the change in the dirty score upon a 0-to-1 switch, holding other variables at their means.

Source: Own estimates

However, a worker holding a specific position is not necessarily facing job loss, as studies suggest that at least some brown-sector workers possess

transferable skills that will ease their job transition to a greener job (Vona, 2018; Tyros, Andrews & de Serres, 2023). Nevertheless, specific sectors, particularly those with decreasing product demand and high capital intensity such as manufacturing, are more likely to face increased adversities. In order to gain a deeper insight into the most vulnerable jobs regarding the effects of decarbonization in Croatia, we depict the structure of high-polluting jobs by occupation in Figure 4.

Figure 4: Structure of high-polluting jobs in Croatia by occupation, 2002-2022



Notes: The percentages in parentheses next to the labels refer to the year 2022. In each year, occupations are sorted from top to bottom according to the share of dirty employment.

Source: Own estimates

The comparison of the structure of dirty employment by occupation between 2002 and 2022 reveals a relatively stable distribution, with a few key occupations dominating the workforce in this category. Heavy truck and bus drivers account for the largest share of dirty employment throughout the 20-year period. Similarly, car, van and motorcycle drivers hold the second-largest share, with their share also remaining stable over time. Together, these two categories represent over 50% of dirty employment, highlighting the transportation sector as a critical area for policy intervention. To the extent that workers in these occupations hold transferable skills, their transition to the less-polluting alternatives would not be too difficult. In the transport sector

and to some extent in the manufacturing one, the brunt of the adjustment burden lies with the employer, who needs to secure sufficient investment in alternative equipment. However, even such cases can lead to a significant decline of employment in a specific sector if employers are not able to secure capital replacements or if new equipment is less labour intensive.

Other notable occupations with moderate contributions include stationary plant and machine operators, and locomotive engine drivers and related workers. These occupations maintain steady shares across the observed period. Smaller, but still significant categories include manufacturing, mining, construction and distribution managers, as well as ship and aircraft controllers and technicians, and sheet and structural metal workers. The contributions of these occupations vary slightly, but do not show substantial upward or downward trends. Smaller categories, such as mining and mineral processing plant operators, handicraft workers and other service managers, collectively account for a minor portion of dirty employment.

Overall, the data suggest that the structure of dirty employment has remained remarkably consistent over the two decades, with no substantial shifts in occupational shares. This stability implies that technological advancements or policy interventions have not drastically altered the composition of these jobs in Croatia. Thus, future policy interventions are expected.

In general, policy efforts should be directed towards addressing the identified and anticipated labour market shortages, and devising upskilling and reskilling educational programs capable of smoothing the transition (Chun, 2024). The existing evidence reveals that integrating the relevant, standardised, clean transition-related learning topics into mainstream training and degree courses in formal higher and vocational education and training remains demanding, not only in Croatia but also in other EU economies (ETF, 2023; Gustavson, Lundkvist & Thunqvist, 2025). However, without specific data evidence on the most important sectors where interventions are needed, the policy efforts could miss the target.

CONCLUSION

The aim of this paper is to identify the prevalence of high-polluting jobs in Croatia, in order to facilitate future research on the effects of the green transition process on the Croatian labour market, as well as to provide initial evidence on the segments of the labour market most likely in need of policy intervention. To that end, by relying on a recently developed methodological

framework, the share of high-polluting jobs in Croatia was estimated, providing comparable estimates to other European economies.

According to our estimates, Croatia has a share of high-polluting jobs comparable to the average of other European economies. Most high-polluting jobs are in the transport industries, followed by manufacturing. The typical worker in a high-polluting job is likely to be male, a younger worker, a person with medium or low educational attainment, and working in Northern or Adriatic Croatia. We have not identified any substantial differences between urban and rural locations of high-polluting jobs. However, this does not imply that a more detailed inspection would not detect specific geographical areas with increased worker vulnerability to the effects of the green transition. Analysing the dynamics of high-polluting jobs share in the 2002-2022 period reveals a relatively modest decline, implying that significant changes are yet to be expected. Thus, this paper calls for an even more detailed analysis, in order to provide relevant inputs for upskilling and reskilling policies.

Although our results provide an initial framework for policy discussions, they also have several limitations. As in other contributions following the same methodological outline, the major shortcoming is reliance on the O*NET classifications (Dicarlo et al., 2016), which have significant differences compared to the European multilingual classification of skills, competences and occupations (ESCO) when it comes to green jobs taxonomy (Maldonado et al., 2024). Since ESCO is still developing, it is expected that the application of this taxonomy to Croatian data will yield more precise information on important venues for policy action.

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THE INNOVATION ECOSYSTEM IN CROATIA

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Croatia strives to improve the overall social and economic sustainability through an innovation ecosystem that encompasses a wide range of initiatives, institutions, and technological advancements. The key players in this process include research centers, start-ups and policies supporting sustainable development. The aim of this paper is to analyze the innovation ecosystem of the Republic of Croatia, with a special emphasis on identifying the key elements and initiatives that contribute to social and economic sustainability. The research methodology includes a qualitative approach through in-depth interviews with key stakeholders of the innovation ecosystem in Croatia and the implementation of a SWOT analysis. The SWOT analysis serves as a tool that enables a comprehensive assessment of the state of the innovation ecosystem and provides a framework for identifying the key strengths, weaknesses, opportunities, and threats within the system. By applying it to the innovation context of Croatia, it is possible to identify the key factors influencing the ecosystem's performance — areas that require improvement and resources that can be strategically utilized for further development and growth of innovations. The research was conducted as part of the EMPOWEREDbyNEIA project, between January and June 2024. The sample of 12 participants included representatives from research and development organizations (from the academic community), the economic sector (industry), entrepreneurial support institutions, i.e. business incubators, competence centers and local government units (from the state), and representatives of the civil so-

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ciety (citizen associations and individuals). The SWOT analysis revealed that the innovation ecosystem in Croatia has strengths such as a well-developed culture of innovation and networking, but it faces challenges like the lack of consistent government support, weak investments in research and development, and inadequate cooperation between academia and industry. Key opportunities for improving the system are identified in the optimal utilization of EU funds and the promotion of green and digital transitions, while the main threats include dependence on external funding sources and lack of a long-term strategy. The results of the conducted research indicate the need to improve cooperation between all stakeholders of the innovation ecosystem, increase investments in research, development and innovation, create a more flexible and supportive regulatory framework and ensure continuous financial support for research and development activities. Only through strategic planning and coherent policy implementation can the Republic of Croatia achieve sustainable growth and competitiveness in the global market.

Key words: *innovation ecosystem, sustainable development, innovation and entrepreneurship, SWOT analysis, Croatia*

JEL classification: *010, 031, 032, 033, 038*

INTRODUCTION

The concept of innovation ecosystem has gained significant momentum in recent years, as organizations and policymakers seek to foster an environment conducive to the development and commercialization of new ideas. This approach recognizes that innovation is not an isolated endeavor, but rather the result of complex and dynamic interactions between various stakeholders and institutions within a broader ecosystem (Filatova et al., 2020). However, the diversity of existing innovation ecosystems has led to conceptual ambiguity and a lack of clarity regarding their key characteristics and boundaries (Klimas and Czakon, 2021). Despite these challenges, the concept of innovation ecosystem has emerged as a promising approach in the literature on strategy, innovation and entrepreneurship, building on the well-established framework of business ecosystems (Gomes et al., 2018). Another key aspect of innovation ecosystems is their inherent complexity, which can be viewed through the lens of complex adaptive systems (Russell and Smorodinskay, 2018). This complexity arises from the multitude of interactions and interdependencies between different

actors, including companies, research institutions, government agencies and supporting infrastructure (Filatova et al., 2020).

The New European Innovation Agenda (NEIA), adopted in 2022, is a strategic initiative aimed at strengthening Europe's innovation capacity and competitiveness on the global stage. This program is based on the understanding of innovation as a key driver of economic growth, job creation and societal well-being (European Commission, 2022). However, realizing the full potential of innovation requires a holistic and inclusive approach that addresses both the technological and non-technological aspects of the innovation ecosystem (Miroux et al., 2021). Historically, innovation ecosystems have been primarily viewed through the lens of technology and commercialization (Thompson et al., 2012). While this perspective remains important, the New European Innovation Agenda adopts a more comprehensive view, emphasizing the need to foster inclusivity, sustainability and collaboration among diverse stakeholders (Miroux et al., 2021). In the context of the Republic of Croatia, implementing this agenda can significantly contribute to strengthening the domestic innovation ecosystem. As a member of the European Union, Croatia has the opportunity to leverage the guidelines and resources of this agenda to enhance its innovation capacities. This includes strengthening the cooperation between academia, industry and the public sector, as well as increasing investment in research and development. The New European Innovation Agenda also places a strong emphasis on inclusivity and sustainability, which is particularly important for Croatia in addressing societal and economic challenges such as energy sustainability, digital transformation and food security. Through the strategic application of innovative procurement, Croatia can modernize public services, stimulate economic growth and create jobs in high-tech sectors. Promoting and supporting talent is also crucial, ensuring that the best experts have the opportunity to develop and contribute within the Croatian ecosystem.

The aim of this paper is to explore the innovation system in Croatia, with a focus on identifying the key challenges and opportunities for its development. The research questions addressed in the paper are the following:

How can the innovation ecosystem in Croatia be improved by identifying the key challenges and opportunities?

What are the key factors that most contribute to the country's social and economic sustainability in the context of the implementation of the New European Innovation Agenda?

CHALLENGES IN CROATIA'S INNOVATION SYSTEM

The concept of the “innovation ecosystem”, as described by Granstrand and Holgersson (2020), represents a dynamic network of actors, activities and resources aimed at addressing societal challenges. In Croatia, the innovation system operates through the collaboration of government, academia and industry within the “triple helix” model, fostering knowledge creation, dissemination and commercialization (Etzkowitz and Leydesdorff, 1995). Key actors such as the Ministry of Science and Education, the Croatian Science Foundation and various innovation agencies play a crucial role in implementing strategies like the Smart Specialization Strategy (S3), which prioritizes sectors such as ICT, bioeconomy and health (Government of the Republic of Croatia, 2016; Švarc, 2015; Jaklič et al., 2014). However, institutional frameworks often suffer from a lack of coordination and strategic focus. Improved collaboration between research institutes and technology parks is needed to accelerate the commercialization of knowledge (Žaja et al., 2013).

Despite this supportive framework, Croatia faces significant challenges, including limited funding, bureaucratic obstacles, weak collaboration between academia and industry, and insufficient international partnerships (Banić et al., 2020; Švarc, 2014). Vlačić (2021) highlights the vulnerability of transitional economies like Croatia to global crises, calling for strategic shifts toward sustainable smart industry. A lack of strategic coordination and standardized innovation management systems (SIMS) further hinders progress, as does the ongoing issue of “brain drain”, which undermines the innovation potential (Idris and Durmuşoğlu, 2021). Lundvall (1992) highlights the critical importance of interaction between companies, universities and policymakers for having a successful innovation system, a dynamic that remains underdeveloped in Croatia.

Strategic partnerships between universities, public institutions and industries are essential for fostering innovation. Perić (2021) emphasizes the need for collaborative research and development projects and an active involvement of business professionals in education in order to strengthen knowledge transfer and innovation capacity. Similarly, Wilson (2008) advocates for building trust between entrepreneurs and institutions through joint educational initiatives and everyday collaboration. Chesbrough and Tucci (2020) stress the importance of connecting innovators with businesses to ensure that new ideas are commercialized and reach the market.

Building an entrepreneurial mindset is equally crucial for advancing innovation. Delanoë-Gueguen and Liñán (2019) argue that fostering entrepreneur-

rial thinking within organizations enables innovative approaches to everyday tasks, enhancing productivity and adaptability. Carsrud and Brännback (2011) emphasize the importance of creating platforms that facilitate interaction among innovators, producers, investors, and customers, boosting persistence and motivation in business development. These efforts are particularly relevant in education, where practical, hands-on experiences must align with labor market needs to equip individuals with skills for a dynamic economic environment (Pittaway and Cope, 2007; Przepiorka, 2016).

Effective innovation also depends on strong policies and infrastructure. Gertler and Wolfe (2004) highlight the need for streamlined administrative procedures, investments in infrastructure, and tax incentives in order to attract and support entrepreneurs. Croatia must also focus on aligning educational curricula with the industry demands, especially in addressing skill shortages in the key areas (Przepiorka, 2016).

While Croatia's innovation system has laid a foundation through strategic initiatives, addressing the gaps in coordination, partnerships, and infrastructure is essential. Strengthening these areas can enhance Croatia's position within the global innovation ecosystem and promote sustainable economic growth.

METHODOLOGY

The research methodology is based on a qualitative approach that includes in-depth interviews with key stakeholders of regional innovation systems and the implementation of a SWOT analysis. The research was conducted as part of the EMPOWEREDbyNEIA¹ project, which explores the functioning of regional innovation systems and the role of the New European Innovation Agenda (NEIA). The main goal of the project is to improve and strengthen regional innovation ecosystems by facilitating collaboration and connecting various European innovation ecosystems. The project focuses on strengthening cooperation among the key stakeholders of the Quadruple Helix² through an inclusive, gender-sensitive mutual learning process at both regional and national levels, as well as on developing joint tools and resources for scaling

¹ Project title: "Ecosystems Mapping and Planning through Open Dialogue for Wider Cooperation across EU Regions Based on the Entrepreneurial Discovery Project," funded by the European Union's Coordination and Support Action program under grant agreement number 101134912

² University-Industry-Government-Civil Society

innovation. The consortium brings together experts from seven European countries: Italy, Austria, Poland, Romania, Bulgaria, Croatia and Estonia, and is funded by the European Union's Horizon 2020 program.

The Croatian partner, TERA Tehnopolis d.o.o. conducted data collection within the HR NUTS 2 region (statistical region level 2), which defines the main regions for the application of regional policies. HR NUTS 2³ consists of four non-administrative units formed by grouping counties as lower-level administrative units. For the conducted research, the Panonian Croatia region was selected⁴.

Interactive discussions with the key stakeholders of the Quadruple Helix were conducted through one-on-one (1:1) qualitative interviews using a semi-structured questionnaire that enabled the collection of in-depth insights and diverse perspectives from carefully selected participants. The sample of 12 respondents included representatives from research and development organizations (representing academia), the economic sector (industry), business support institutions such as business incubators, competence centers, local government units (representing the state) and representatives of the civil society (citizen associations and individuals). The research was conducted by TERA Tehnopolis experts with expertise in innovation ecosystems, technology transfer and the application of design methods (design thinking and design science) in the period between January and June 2024. Upon the completion of the research, an internal discussion was held at TERA to analyze the collected insights and experiences. Key information was identified, coded and structured according to SWOT quadrants, terms were grouped and the groups were named. The results were documented as a SWOT analysis, providing the foundation for further strategic recommendations and measures for improving the innovation system in Croatia.

³ **HR NUTS 2** includes the regions of Pannonian Croatia, Adriatic Croatia, the City of Zagreb, and Northern Croatia

⁴ **Pannonian Croatia:** Bjelovar-Bilogora County, Virovitica-Podravina County, Požega-Slavonia County, Brod-Posavina County, Osijek-Baranja County, Vukovar-Srijem County, Karlovac County, Sisak-Moslavina County

RESULTS AND DISCUSSION

The innovation ecosystem of the Republic of Croatia is a key element for achieving sustainable social and economic development. The aim of the analysis was to gain a deeper understanding of regional innovation systems and of the potential for implementing NEIA, contributing to strengthening the innovation capacities and competitiveness of the EU. Table 1 presents the SWOT analysis of the innovation system of the Republic of Croatia.

Table 1: SWOT Analysis of the Innovation Ecosystem of the Republic of Croatia based on the NUTS 2 Region

STRENGTHS	WEAKNESSES
• developed culture of innovation acceptance • developed culture of improvisation • innovators' readiness for networking • transnational mindset of individual innovators • Croatia is not saturated with intense innovation efforts • inertia of the state system allows for unhindered research, development and innovation (if sufficient funds are available) • significant and ongoing need for innovation • established infrastructure that can be used for innovation processes (incubators, technology parks, business support institutions)	• inconsistency or discontinuity in government plans (or their implementation) regarding R&D&I • "Innovation" is mostly used as a bureaucratic "cliché," rather than genuinely in spirit and concept • insufficient national effort to attract and support innovations in Croatia • lack of long-term perspective within the academic community • researchers are not market-oriented, nor are they encouraged to be • no registry or database of available resources from the academic community (expertise, knowledge, IP, laboratories, equipment, etc.) • no active testing grounds or other organized structures that support innovation; equipment and expertise exist, but are not connected or utilized • general lack of practical experience in conducting innovative processes • underdeveloped innovation ecosystem (private and academic sectors) • collaboration between industry and academia is rare, more of a coincidence than the result of a plan or strategy • missing formal structure to connect the private and public sectors • lack of regulatory framework defining the formation of university entities through spin-offs/outs, and the absence of spin-off tradition • insufficient efforts for cross-sector collaboration

OPPORTUNITIES	THREATS
•adoption of Open Source & GPL (General Public License) solutions as a path towards a more cost-effective innovation process •accumulated industrial knowledge/heritage from older generations •an open/unexplored field of research and improvisation culture (“behind closed doors”) •Croatian landscape as a testing ground for innovations •a super mix of contexts: urban, rural, agricultural, natural, coastal, lowlands, mountains, hills, low-tech and high-tech, with very good digital and transport connections •top-down support approach: new open calls for connecting the private sector and academia •top-down support approach: open calls for technology transfer activities by the Ministry of Science and Education provide access to funds for technology transfer and innovation (R&D&I) •green and clean technology activities are increasingly supported by EU funds •Croatia cannot compete with strong industrial nations in production, but it can lead as an innovation hub	•a mindset in the industry that is reluctant to accept innovation-related risks •lack of knowledge and practices for risk mitigation in academia and industry •unstructured approach to R&D&I processes by small and medium-sized enterprises •fear of costs and losses associated with innovation hinders innovation (fees, legal proceedings, stolen ideas, etc.) •research and development accounting practices are not widely known, even among accountants •national financial support and private investments in innovation are minimal; innovation programs are mostly funded by EU funds •the current EU funding program is known to the public for the period until 2027 (long-term perspectives are unknown to stakeholders – lack of information for planning) •problematic planning and execution of projects funded by the state/EU due to government bureaucratic inertia •incoherence and lack of attention in the implementation of funding programs by the Government •misalignment between innovation processes and funding program cycles •lack of an objective, transparent, unified, formalized and balanced approach to administrative procedures related to innovation, decision-making processes and staff recruitment •available R&D&I infrastructure is underutilized •technology transfer offices and business support organizations lack the expertise to successfully support technology transfer processes, jeopardizing the execution of innovation processes and the realization of innovations •a silo mentality is present in public and private organizations •brain drain and idea loss due to: “Better opportunities elsewhere,” “It’s corrupt here,” “You don’t have the support to succeed here,” “It’s easier to earn money somewhere else”

Source: Authors as cited in Boehning, Kovač & Šarić (2024)

The conducted SWOT analysis reveals that Croatia has a strong cultural foundation for embracing innovation, characterized by a local culture of improvisation that fosters individual creativity and innovation. There is a strong desire for innovation, which further motivates creativity and inventiveness. Individual innovators often cross borders to connect with like-minded individuals, demonstrating a transnational approach crucial for global networking and collaboration. This aligns with earlier findings by Žaja, Varga and Švarc (2013), who noted that Croatia's innovation culture and infrastructure offer a solid base for global networking, although these strengths are often underutilized. Positive public response to local innovations also serves as an additional motivator for innovators. Croatia is also identified as a naturally suitable environment for innovation and experimentation, as it is not saturated with intense innovation efforts. Such a setting is echoed in Vlačić's (2021) argument that transitional economies like Croatia can leverage their less saturated environments as testing grounds for innovation.

Due to the inertia of the state system, Croatia provides a safe environment for research and development. There is a significant need for innovation as a result of the less-developed economic context, which demands improvements in business processes, digitalization and business modernization. The available infrastructure, such as incubators, technology parks and other forms of business support institutions, can be utilized for innovation processes. This observation resonates with the findings of Jaklič et al. (2014) who highlighted the role of infrastructure in fostering innovation, but noted the need for a better integration and utilization of these resources.

On the other hand, the lack of cooperation and alignment between national actors related to research, development and innovation (R&D&I) has emerged as one of the major weaknesses and challenges of the ecosystem. "Innovation" is often used as a bureaucratic term without real implementation. The academic community in Croatia suffers from a lack of long-term perspective and market orientation. These issues reflect the systemic barriers identified by Banić, Tomišić and Duplančić (2020), who pointed out inconsistent government policies and insufficient alignment between academia and industry as key hindrances to innovation. The absence of centralized databases on available intellectual property resources, competences and knowledge, as well as a lack of active testing grounds and organized structures supporting innovation, further aggravate the situation. Researchers are not sufficiently encouraged to adopt a market-oriented approach, and the practice of implementing innovative processes is underdeveloped. Idris and Durmuşoğlu (2021) similarly emphasized the importance of standardized

innovation management systems (SIMS) to address such inefficiencies and improve coordination across the ecosystem.

A key opportunity to mitigate these weaknesses lies in maximizing the use of available financial resources through EU funds dedicated to the development of green and digital economy. Open calls for collaboration between the private sector and academia offer additional opportunities for cooperation and technology transfer. Croatia has the potential to position itself as an innovation hub, despite being unable to compete with larger industrialized countries in terms of production output. This aligns with the Smart Specialization Strategy (Government of the Republic of Croatia, 2016) which emphasizes leveraging EU funds to drive innovation and foster sustainable industries. Unfortunately, this also poses a threat to the successful development of the innovation ecosystem, as national financial support for innovation is nearly non-existent. Most innovation programs are funded exclusively by EU funds, and uncertainty surrounding long-term funding prospects after 2027 further complicates the planning and implementation of innovation projects.

The lack of coherence and organization in the implementation of financial programs also presents a significant threat. Industry and academia are reluctant to take on the risks associated with innovation. The lack of a structured approach to R&D&I processes in small and medium-sized enterprises (SMEs) further exacerbates the situation. The fear of costs and losses associated with innovation can significantly hinder innovation efforts. Finally, the lack of transparency in administrative procedures related to innovation represents a serious obstacle to the further development of the system. These barriers, as highlighted by Chesbrough and Tucci (2020), emphasize the critical need for stronger connections between innovators and businesses in order to ensure an effective commercialization of innovations. The available resources resulting from years of investment in innovation infrastructure and the development of a network of business support institutions are often not utilized correctly, and the available infrastructure has not been brought to its intended purpose. Organizations that are supposed to support innovation often lack the necessary expertise and experience in implementing complex technology transfer processes. Widespread public distrust in government projects further hinders innovation processes.

The SWOT analysis of the innovation ecosystem of the Republic of Croatia reveals the deep complexity of the challenges and opportunities that the country is facing. While strengths, such as the cultural acceptance of innovation and a natural environment for experimentation, provide a solid foundation, weaknesses like the lack of cooperation from the state and academic isolation require urgent reforms. The identified fragmented approach aligns with Žaja, Varga and

Švarc's (2013) observations on limited coordination among the key stakeholders in Croatia's innovation ecosystem. The SWOT analysis of the innovation ecosystem, based on the Quadruple Helix model, which includes academia, industry, government and civil society (the public), highlights the differences in attitudes and perceptions among these participants regarding the goals and priorities each segment of the Quadruple Helix has, as well as the differences in trust and willingness for mutual cooperation. Each group within the Quadruple Helix uses its own indicators to measure success and, in this context, recognizes different opportunities and threats for achieving results. The industry emphasizes the commercialization of innovations, profitability, and speed to market. On the other hand, academia tends to focus on long-term outcomes derived from fundamental research, and it is neither sufficiently market-oriented nor adequately encouraged in this regard. Such disparities reflect the need for harmonized objectives across the Quadruple Helix, as underscored by Idris and Durmuşoğlu (2021). Both sides agree that available resources and access to funding are insufficient. According to the responses, the lack of a long-term funding perspective complicates planning for both groups of the Quadruple Helix. Opportunities for development through EU funding are significant, but threats such as dependence on external funds and a lack of preparedness could hinder progress.

CONCLUSION

The innovation ecosystem of the Republic of Croatia is crucial for achieving sustainable social and economic development. The conducted SWOT analysis highlights the features that shape its potential. A developed culture of innovation acceptance and improvisation, along with the infrastructure of business support institutions, provides a solid foundation for growth. The transnational approach of innovators further strengthens the capacities for global cooperation and the exchange of ideas. However, there are also significant weaknesses. A lack of consistency in government plans and policy implementation, along with a weak market orientation among researchers, hampers progress. "Innovation" is often used as a bureaucratic "cliché" without real implementation, and the national strategy is ineffective in attracting and retaining innovations. The absence of centralized databases and a lack of active testing grounds further complicate the situation.

Opportunities for improvement are significant, especially through the maximum utilization of EU funds dedicated to the development of green and digital economy. Open calls for collaboration between the private sector and academia provide additional opportunities for technology transfer. Croatia has

the potential to position itself as an innovation hub by leveraging its natural advantages and infrastructure, which supports experimentation and development. However, reliance on external funds poses a risk, particularly given the uncertainty regarding long-term financial perspectives after 2027. The lack of coherence in the implementation of financial programs and the fear of costs and losses associated with innovation may also hinder innovation efforts.

The industry and academic community in Croatia are not inclined to take risks associated with innovation, thus further complicating the situation. The lack of a structured approach to research, development and innovation (R&D&I) processes in small and medium-sized enterprises (SMEs) further hinders the implementation of innovations. Additionally, widespread public distrust in government projects, perceived as too expensive and ineffective, further hampers innovation processes.

For Croatia to realize the full potential of its innovation ecosystem, it is essential to improve cooperation between all stakeholders, including the public sector, academia and the private sector. Increased investment in research, development and innovation is necessary, along with the development of a more flexible and supportive regulatory framework and the provision of continuous financial support for research and development activities. Furthermore, it is necessary to develop and implement educational programs and training that will equip participants with the skills and knowledge required for the implementation of innovation processes, from participation in research and development processes, intellectual property protection and the creation of intangible intellectual assets, to prototype development, innovation testing and optimization. In this context, it is important to encourage partnerships between universities, public institutions and business entities in order to ensure a successful implementation of research and development projects. Increased cooperation among all stakeholders can be achieved through strategic planning and coherent policy implementation that fosters synergy between different sectors.

The key to success lies in the continuous improvement and adaptation of the innovation ecosystem to changes in the global environment. Croatia must be ready for flexible and swift adjustments so as to maintain its competitiveness and ensure sustainable growth. Only through strategic planning, effective policy implementation, and continuous investment in innovation can Croatia achieve its goal of becoming a leader in innovation on the global market.

One limitation of this research is its reliance on the SWOT analysis, which may be subject to subjective interpretation by researchers, as well as the limitation of case studies that may not reflect the full complexity of the innovation ecosystem in the Republic of Croatia. Additionally, the lack of longitudinal data

may limit insights into long-term trends and the effects of specific initiatives. Future research should include longitudinal studies in order to track the development of the innovation ecosystem over a longer period and evaluate specific policies and initiatives through both quantitative and qualitative methods. It is recommended to expand the research by comparing it with the innovation ecosystems of other countries in the region in order to identify best practices and potential areas for improvement. The results of the research presented in this paper, published for the first time, can serve as a basis for comparison.

ACKNOWLEDGMENT

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SUCCESS DETERMINANTS OF GREEN CROWDFUNDING CAMPAIGNS FROM CEE COUNTRIES

Marija ŠIMIĆ ŠARIĆ*, Matko ŠARIĆ**

Entrepreneur initiatives considered green are those that are primarily environmentally oriented, and these ventures are referred to as green ventures. As well as with all ventures, in order for them to be created and to survive in the market, financial resources are needed. In contrast to classic ventures, it is more difficult for green ventures to access external sources of financing because of higher information asymmetry, longer payback periods and uncertain returns due to political risks. Crowdfunding emerges as a possible solution to the financing problem, i.e. a special type of crowdfunding, the so-called green crowdfunding. Green crowdfunding is crowdfunding oriented to projects that have a positive environmental impact. Those projects are sustainable and eco-friendly, focused on climate resilience, green technology, sustainable agriculture and renewable energy.

Many authors have analysed the crowdfunding success determinants, but there is a lack of research on success determinants in the field of sustainable and environmentally friendly projects. Furthermore, to the best of the authors' knowledge, there is no research on the determinants of the success of green campaigns for the countries of Central and Eastern Europe. Due to the above-mentioned, our research objective is to determine and explain the important factors influencing the success of crowdfunding campaigns for green projects in CEE. Therefore, we extracted 35 out of 1318 green projects from CEE countries using Kickstarter dataset and Py-

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thon programming language. This was done by detecting keywords related to green crowdfunding, such as “sustainable”, “ecologic”, “recycled”, “renewable” and “organic”, and “zero waste”, “eco-friendly”, “inside campaign blurbs (brief descriptions)”. We examined the factors influencing the probability of project success. Two logistic regression models were employed on the collected dataset, taking into consideration three independent variables: the number of backers, duration and project goal. The obtained results show that the number of backers is positively correlated with the probability of campaign success, while the project goal and project duration are not statistically significant.

Keywords: *Green crowdfunding, sustainable, success determinants, finance, CEE*

JEL classification: *G11, G20, G40, Q01, Q56*

INTRODUCTION

Sustainable entrepreneurs, who deal with social and environmental problems such as biodiversity loss, climate changes etc., and offer new, innovative services, products or processes, face a higher business risk and market uncertainty (Petruzzelli et al., 2019; Tenner and Hörisch, 2021; Yao, 2025). This risk leads to difficulties in accessing adequate sources of financing (Bento et al., 2019; Corsini and Frey, 2023). Crowdfunding appears as a possible source of financing that could fill this gap (Petruzzelli et al., 2019; Bento et al., 2019; Böckel et al., 2020; Tenner and Hörisch, 2021; Corsini and Frey, 2023; Caré et al., 2025). Crowdfunding represents (Šimić Šarić and Musap, 2024) “a new method for financing projects, which vary in purpose, size, from small art projects to entrepreneur’s project collecting from several hundred to thousands of euros, by many individuals around the world using the Internet”. In this case, thanks to access to the Internet, ordinary people can finance a wide range of projects from commercial, environmental or social areas (Adamska-Mieruszevska et al., 2023), expecting a reward or a share in the project. Four types of crowdfunding are distinguished in the literature, namely donation-based, reward-based, equity-based, and lending-based (Šimić Šarić et al., 2022). Furthermore, two different funding phases exist, which are the pre-funding phase and the post-funding phase. The first phase, the pre-funding phase, refers to campaign planning and preparation, communication with the potential backers and marketing. It includes the time of campaign duration. Contrary, the

second phase of the campaign, the post-funding phase, starts after the end of the CF campaign. In this phase, the project owners must inform the backers of its success or failures, distribute what is promised in the campaign, e.g. rewards, returns, and most importantly, realize the project taking into account the advertised measures (Böckel et al., 2020). A lot of research on crowdfunding and the determinants of its success exists (Belleflamme et al., 2013; Lukkarinen et al., 2016; Mollick, 2014; Šimić Šarić, 2021; Šimić Šarić et al., 2022; Šarić and Šimić Šarić, 2023; Šimić Šarić and Musap, 2024), but a research gap appears in the field of environmentally friendly projects (Predkiewicz and Kalinowska-Beszczyńska, 2020) and sustainability (Petruzzelli et al., 2019; Bento et al., 2019; Böckel et al., 2020; Tenner and Hörisch, 2021; Corsini et al., 2024). This is a part of green crowdfunding. This type of crowdfunding refers to green projects, which have a positive environmental impact. Those projects are sustainable and eco-friendly, focused on climate resilience, green technology, sustainable agriculture, renewable energy, reduction of carbon dioxide emissions etc. (Adhami et al., 2017). In the literature, there is a lack of studies about the success determinants in green crowdfunding campaigns. In addition, there is a lack of research on the state of crowdfunding in the CEE region, the countries' legislation and focus on green projects. Due to that, our contribution lies in the theoretical overview of the state of crowdfunding in the CEE region, the legislation and the limitations of financing sustainable projects. Furthermore, the contribution is in the analysis of the impact of basic success factors on the success of green crowdfunding projects from the CEE region launched on the Kickstarter platform, due to their undefined impact in previous research (Yang et al., 2019) and the lack of research on campaigns from the CEE region. The focus is on reward-based crowdfunding, where the backers can be the future potential customers (Bento et al., 2019).

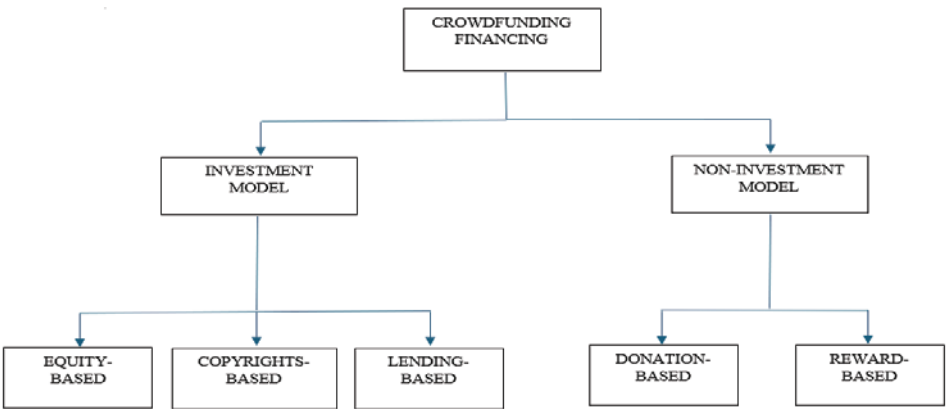
The organization of the paper is as follows. After the introduction, a theoretical review of green crowdfunding, state of crowdfunding, legislation and green projects in the CEE region and the success determinants is provided. After that, the methodology is presented, including data collection, measures, data analysis, results and implications. The paper ends with the conclusion and references.

THEORETICAL REVIEW

GREEN CROWDFUNDING

The development of crowdfunding intensified in 2008 during the financial crisis, due to the lack of other finance sources such as venture capital, business angels, banks etc., as well as the development of the World Wide Web 2.0, which resulted in better communication and interaction among its users (Đurđenić, 2017; Krok, 2019). Crowdfunding (CF) is an example of digital transitions in finance, as it represents the practice of financing projects/ideas/products by gathering money from a crowd via the Internet, that is, using different crowdfunding platforms (Ninčević Pašalić and Pepur, 2022). In addition, it is part of a wider alternative finance market (Bergmann et al., 2021). According to Shala (2022), the volume of crowdfunding will grow to \$300 billion in 2025, which will outperform the investments of venture capital and business angels. The crowdfunding platforms do not lend, borrow or aggregate money in their name, but allow backers to invest (Hariwibowo, 2024). Two models of crowdfunding exist: the investment model and the non-investment model. The investment model includes crowdfunding based on equity, crowdfunding based on lending and crowdfunding based on copyrights. The non-investment model refers to reward-based crowdfunding and donation-based crowdfunding (Figure 1).

Figure 1: Crowdfunding classification



Source: Ninčević Pašalić and Pepur (2022)

Reward-based and donation-based crowdfunding are a better fit for sustainable energy and green projects in the first phases, i.e. the inception and prototype phases (Adhami et al., 2017), due to a higher requirement for seed money (Yin et al., 2024). Therefore, two types of green crowdfunding exist (Yang et al., 2019):

- green donation-based – refers to non-profit activities and the construction of a green environment through nature protection;
- green reward-based – applied by organizations that sell green services or products.

The green investments/projects are related to the following (Stein, 2024; FasterCapital, 2024):

- renewable energy (solar power, wind power, hydro power, geothermal power and biomass energy),
- energy efficiency improvements and conservation (green buildings, smart grid technologies, energy storage solutions),
- sustainable agriculture and food production (organic farming, agroforestry, reforestation and afforestation),
- sustainable transportation (electric vehicles, public transportation and alternative fuel vehicles),
- waste management and recycling (circular economy, waste-to-energy technologies and pollution control).

According to Bergmann et al. (2021), a significant gap exists in the financing of renewable energy projects (REP) through crowdfunding, since in 2017 a total of €42.7 bn were invested in those projects by the alternative financing sector and only €300m via crowdfunding. Furthermore, traditional investors are not so inclined to finance sustainable entrepreneurs because they consider them unprofitable and riskier. Due to that, crowdfunding is seen as a supplement financing instrument for this kind of entrepreneurs (Tenner and Blöcker, 2021). However, “the existing literature does not provide unambiguous theoretical predictions nor empirical evidence on the relationship between the sustainability orientation of the ventures and their ability to deliver successful crowdfunding campaigns” (Bento et al., 2019, p. 8). In addition, regarding green crowdfunding, there is a gap that exists primarily in developing economies, in areas such as: social impact of equity crowdfunding, regulatory frameworks, and green CF role in financial inclusion. Furthermore, in low-income countries, sustainable development is supported by crowdfunding facilitating access to clean technologies. In those countries, policy makers must work to reduce the perceived risk associated with sustainable projects, as well as to improve the dissemination of information (Caré et al., 2025).

STATE OF CROWDFUNDING, LEGISLATION AND GREEN PROJECTS IN THE CEE REGION

The CEE region consists of the following 12 countries: Albania, Bulgaria, Croatia, the Czech Republic, Hungary, Poland, Romania, the Slovak Republic, Slovenia, and the three Baltic States: Estonia, Latvia and Lithuania. Although these are 12 different countries, their common trait is that they transitioned from a planned economy to a market economy 30 years ago, and that their financial sector is bank oriented. The bank oriented financial system represents a limitation for growth and therefore it is necessary to diversify the financial sector (Shala, 2022; Seifa, 2025). In addition to the development of private equity, venture capital and business angel markets, it is also necessary to develop the crowdfunding market. The development of crowdfunding is fast, but varies significantly between countries (Di Pietro and Buttice, 2020). The US and China dominate, and in terms of the EU, the development is concentrated in several EU countries like Germany, United Kingdom, France, Italy and the Netherlands (European Parliament, 2017). The CEE EU countries lag behind the other EU members in the use of crowdfunding and its development. In addition, they lag behind in world rank positions as well (Fanea-Ivanovici and Siemionek-Ruskan, 2019). According to Statista (2025), Estonia has 32 crowdfunding platforms and a well-developed crowdfunding market with the highest per capita crowdfunding rates in Europe (Crowdinform, 2025). Most of the other CEE countries have significantly fewer CF platforms, ranging from 2 to 17 platforms. Furthermore, most of the platforms in CEE regions are foreign based, while in Western Europe domestic CF platforms dominate (Odorovic et al., 2021).

Regarding the legal regulation of crowdfunding, many governments worked hard (Ganatra, 2015) to adopt and implement it. The complexity arises from the need to protect all stakeholders involved, and it is necessary to encompass different models. According to Shala (2022), the literature about the regulations of crowdfunding is lacking, especially for the CEE region. Until September 2021, CEE countries had different regulations, but then the EU introduced Regulation (EU) 2020/1503. According to this legislation, all EU member states have the same requirements in terms of authorization, organization and supervision of crowdfunding service providers. In addition, they have the same provisions on crowdfunding services, as well as the transparency and operation of crowdfunding platforms (<https://eur-lex.europa.eu/eli/reg/2020/1503/oj>). Cicchiello (2020) points out how the application of different national regulations increases transaction costs and limits the spread of crowdfunding offerings among EU countries. Furthermore, this leads to the

creation of an unpredictable environment and hire uncertainty, which repels investors and stifles crowdfunding investments. A special problem in terms of legislation remains in the Balkan countries (Table 1): Albania, Bosnia and Herzegovina, Montenegro, Republic of Kosovo, North Macedonia and Serbia, because they do not have a legal framework for crowdfunding, especially for equity crowdfunding (Shala, 2022).

Table 1: Crowdfunding regulation in CEE countries

Country	Equity Crowdfunding (Regulation before 2021)	Regulation (EU) 2020/1503	DC F	EC F	RC F	LC F
Albania	No legislation identified		-	0	-	-
Bosnia and Herzegovina	No legislation identified					
Bulgaria	Unregulated but not prohibited	10/09/21	-	-	-	-
Czech Republic	Regulated under pre-existing regulatory framework	10/09/21	1	1	1	7
Croatia	Unregulated but not prohibited	10/09/21	1	1	7	1
Estonia	Regulated under pre-existing regulatory framework	10/09/21	-	-	-	-
Hungary	Regulated under framework created for this activity	10/09/21	1	1	1	-
Kosovo	Explicitly prohibited		-	0	-	-
Latvia	Unregulated but not prohibited	10/09/21	-		-	-
Lithuania	Regulated under framework created for this activity	10/09/21	-		-	-
N. Macedonia	YES-NO		-	-	-	-
Montenegro	No legislation identified					
Poland	Regulated under framework created for this activity	10/09/21	7	7	12	1
Romania	Unregulated but not prohibited	10/09/21	-	1	-	-
Serbia	YES-NO		-	-	-	-
Slovak Republic	Regulated under framework created for this activity	10/09/21	4	3	1	2
Slovenia	Under the applicable law	10/09/21	-	1	1	-

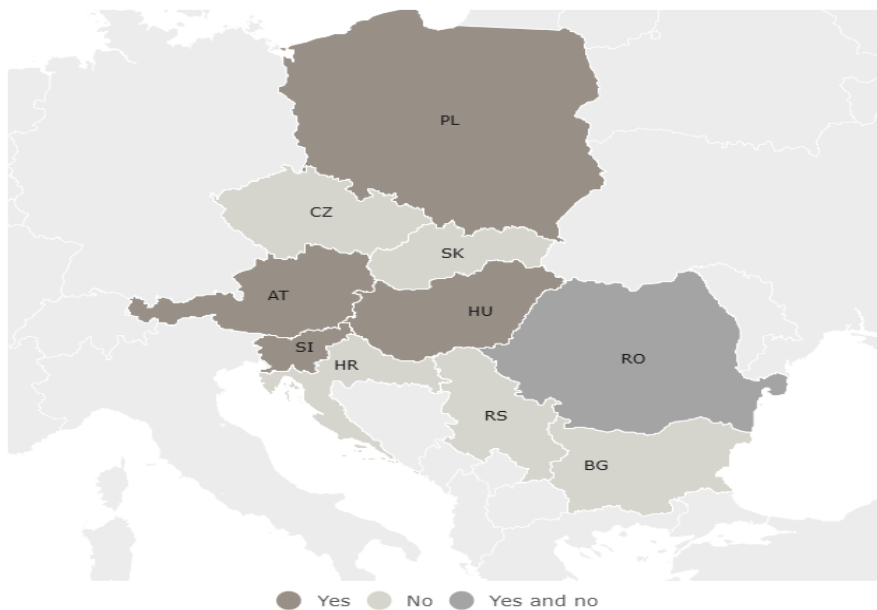
Source: Shala (2022), p. 654

Due to the lack of a legal framework, CEE countries should consider the implementation of a bespoke regime based on market demand, fill the existing regulatory gaps, and improve institutional capacity for enforcing new laws

(Shala, 2022). Furthermore, the existence of crowdfunding-specific regulation positively affects the total CF volume per capita, as well as higher financial freedom, democracy, stronger legal rights, well-developed financial market, and business-friendly legal environment. The impact varies depending on the type of crowdfunding (Kukk and Laidroo, 2020; Di Pietro and Buttice, 2020).

From a global viewpoint, Europe is the fastest warming region (Horky, 2024). Due to that fact, in the long run, countries must make sure that the climate risk translates into financing risk, because investment costs in technologies associated with renewable energies are higher and often ambiguous. The CEE region is more oriented to fossil flues, but for sustainable economic development, it is necessary to reduce their use. Using fossil flues results in higher marginal costs than renewable energy, additionally leading to higher prices and inflation. According to CAN (2024), the CEE region lacks political will and ambition in the field of climate action and energy transition. Figure 2, which presents the regulatory, financial or legal incentive to financing green projects by lending, confirms this. Croatia, the Czech Republic, Romania and Serbia have no regulations. Slovenia and Hungary have them, while Romania has no specific financial incentives, but there are legal/regulatory requirements for credit institutions.

Figure 2: Existence of regulatory, financial or legal incentives to financing green projects by lending



Source: Schöner (2023)

However, the war in Ukraine has resulted in rising energy prices, changing the CEE citizens’ perceptions of energy security and the ways of its consumption. Additionally, it affected the governments, prompting them to undertake renewable energy projects (CAN, 2024).

SUCCESS DETERMINANTS OF GREEN CROWDFUNDING CAMPAIGNS

Research into the success factors of reward-based CF campaigns has resulted in various factors and their significance. Some studies focused on information description, some on the duration and goal, while some combined those two aspects (Mollick, 2014; Šimić Šarić, 2021; Šarić and Šimić Šarić, 2023; Šimić Šarić et al., 2022; Šimić Šarić and Musap, 2024; Corsini and Frey, 2023).

Figure 3 summarises the determinants that influence the fundraising outcomes, but focus on sustainable and eco projects is still rare in the literature.

Figure 3: Determinants influencing the crowdfunding outcomes

Paper	Factors
de Larrea et al. (2022)	Images Communication with donors Title length Description length
Ho et al. (2021)	Title Project description length Location Visual presentations
Mollick (2014)	Personal networks Project quality Geography
Rossolini et al. (2021)	Campaign information structure Environmental protection purposes Goal size
Salahaldin et al. (2019)	Duration
Yuan (2016)	Textual content Topical feature

Source: Yin et al, 2024, p. 3

Predkiewicz and Kalinowska-Beszczynska (2020) analysed the factors affecting the crowdfunding campaign success of eco-projects from 11 different reward-based CF platforms. They concluded that the number of updates and

comments, presence of reward, team/individual description and previous success description have a positive impact, while the target amount has a negative impact on the success of eco-projects. Furthermore, Corsini and Frey (2023) analysed the possibility that crowdfunding could support the evolution of sustainable products, as well as CF determinants of success for such kind of products on Kickstarter and Indiegogo. They extracted 3082 sustainable projects out of a total of 200,000 projects, which represents the share of only 1.5%. According to them, the project goal and campaign duration have a negative and statistically significant impact on the probability of campaign success. That means that, if the project goal is higher and the campaign duration is longer, there is a higher probability of campaign failure. Furthermore, if the campaign description has more words and the keywords are more related to the sustainability of products, there is a higher probability of campaign success. Those two variables are positively related to campaign success, and they are statistically significant.

Yin et al. (2024) analysed 720 green crowdfunding campaigns from the GoFundMe platform, considering the following variables: duration, goal size, city site, length of campaign title, length of campaign introduction, high frequency words, and emotion of campaign introduction, as well as human face appearing in the campaign. According to the study results, the length of campaign introduction, duration and length of campaign title are significant, whereas the other variables did not show statistically significant effects on green crowdfunding campaigns.

Yang et al. (2019) studied 1389 green crowdfunding campaigns from the Chinese platform Tencent Lejuan. They applied a non-linear model to predict project success using the following determinants: goal settings, funds pledge and duration. According to them, project owners should carefully think about two variables – goal and duration – since the authors do not agree on their influence on project success. The impact can be positive, negative or there can be no effect.

Yao (2025) analysed projects from Indiegogo to determine the *green premium* for sustainable in relation to non-sustainable projects. Furthermore, the following key factors were used: the number of backers, number of comments, number of words in the project description, image count, and project owners' crowdfunding campaign experience. Control variables included the goal, duration, updates and price option. The results obtained show that non-sustainable projects have more images, comments and backers but less textual description, and the project owners have more experience. On the other hand, sustainable projects have higher goals and longer duration but fewer price options and up-

dates. According to Caré et al. (2025), backers of green ventures are driven by different motives that go beyond the financial reasons.

Based on the aforementioned, three hypotheses were formulated:

H1: The number of backers positively affects the success of green crowdfunding campaigns from the CEE region;

H2: The project goal negatively affects the success of green crowdfunding campaigns from the CEE region;

H3: The duration of the campaign negatively affects the success of green crowdfunding campaigns from the CEE region.

METHODOLOGY

DATA COLLECTION

The study of the success determinants of green crowdfunding campaigns from CEE countries was performed using Kickstarter campaigns data provided by Webrobots.io in the CSV format. The data included crowdfunding campaigns in the period from the beginning of 2010 to the end of 2024. The campaigns of interest were extracted using the Python programming language and the three following criteria:

- location in one of the CEE countries (country of campaign owner),
- campaign status (successful or failed; those cancelled and suspended were excluded), and
- keywords in the campaign blurb: sustainable, ecologic, recycled, renewable, organic, zero waste, eco-friendly.

A total of 35 out of 1318 green crowdfunding campaigns from the CEE region were detected, whereby 19 campaigns were successful and 16 had failed. It should be noted that this dataset is not the subset of data used in a previous work (Šimić Šarić, M. (2021)). The dataset in the previous paper includes campaigns in the period from June 2010 to February 2018, while the new dataset consists of campaigns from the beginning of 2010 to the end of 2024, meaning that in the proposed study, campaigns from the last 6 years are also considered.

MEASURES

The project success is mostly measured as a dichotomous variable or as the total amount raised by the project (Thomas et al., 2018; Usman et al. 2022). The funding levels can differ over the project time and from project to project, therefore, project performance can be measured in different ways. In this study, the project success was taken as a binary variable (success/failure). According to the applied model on Kickstarter, AON, the campaign is considered successful if it has collected at least 100% of the target amount (set goal). Otherwise, it is considered as failed, and the project creator does not receive any funding.

Due to the theoretical review of green crowdfunding success determinants and the availability of data for CEE green crowdfunding campaigns, the following determinants were analysed:

- The number of backers

The number of backers represents the number of campaign supporters (funders/investors). Project creators create and present promotional materials to encourage potential backers for the investment.

- Project goal

Project goal is the target amount that the project creator plans to raise with a crowdfunding campaign. Project costs should be calculated carefully so as to set an adequate goal. Setting a low target amount increases the risk of project failure, while a high target amount decreases the campaign success probability. Moreover, in order to run a better media campaign, it is necessary to set a satisfying project goal.

- Duration of the campaign

Duration is determined before campaign launch by setting the end date. It is related to the time required for campaign promotion, and therefore should not be too short. On the other hand, long duration can indicate the founder's incertitude regarding his/her own project. A campaign can end before the deadline if it has failed or if multiple target amounts were achieved. In the relevant research, it has been shown that campaign duration is a significant determinant of campaign success, and successful campaigns have a shorter duration.

Table 2 provides the descriptive statistics for the observed variables. According to the data, the mean value for the number of backers who supported the campaigns is 139.66, i.e. nearly 140 backers per campaign. The maximum value equals to 1399 backers, while the minimum number of backers who supported a campaign equals to 0. The data show a large range when it comes

to the number of backers per campaign. The mean value for the project goal is \$35,144.26, with the minimum value of \$499 and the maximum value of \$450,000. The standard deviation equals \$80,375.97. The average value of the duration of the campaigns is 36.28 days, with the minimum value being 14.09 days and the maximum value 60 days.

Table 2: Descriptive statistics

Variable	Mean	Standard Deviation	Min	Max
Number of backers	139.66	294.90	0	1399
Project goal (\$)	35,144.26	80,375.97	499	450,000
Duration (days)	36.28	11.79	14.09	60.00

Source: Authors

DATA ANALYSIS AND RESULTS

Logistic regression analysis was applied to the collected data. Regression analysis “allows for investigation of the relationships between a dependent variable and several independent variables, indicating if the independent variables have a significant relationship with the dependent variables and the relative strength” (Corsini and Frey, 2023). Logistic regression is then used to model the binary dependent variables – campaign success. Calculations were done using the Python package statsdata.

If in a regression analysis two variables are in a perfect linear combination with one another, it is a multicollinearity problem. To avoid this problem, it is necessary to compute the tolerance and variance inflation factors (VIFs) for all variables in the model. Low variance inflation factor values between 1 and 5 revealed that multicollinearity was not present in the empirical models (Table 3.)

Table 3: VIF results for two models

Variables	VIF (model 1)	VIF (model 2)
Number of backers	1.008	1.028
Project goal	1.008	1.013
Duration		1.027
Constant	1.47	2.675

Source: Authors

Two logistic regression models were created (Table 4): the first one with the number of backers and project goal as independent variables, while for the second one campaign duration was added as regressor. Since we have a relatively small sample of 35 campaigns, there is a risk of overfitting and bias in coefficient estimates. Therefore, we limited the maximum number of predictors to 3 according to the widely adopted minimal guideline criterion of 10 events per variable (EPV) (Peduzzi et al., 1996). LLR p-values for our models (Table 3) are far below the conventional threshold value of 0.5 indicating that the null model is likely inadequate in both cases.

Table 4: LLR p-values for two models

Model	LLR p-value
Model 1	$3.756 \cdot 10^{-8}$
Model 2	$1.531 \cdot 10^{-7}$

Source: Authors

In order to assess the goodness of the model fit, we calculated the Nagelkerke pseudo R-squared value and performed the Hosmer-Lemeshow test (Long and Freese, 2006). Table 4 shows that for both models the pseudo R-squared values are around 0.83, and the Hosmer-Lemeshow p-values are close to 1, indicating a good fit of our logistic regression models.

Table 5: Goodness of the model fit

Model	Nagelkerke pseudo R-squared	Hosmer-Lemeshow p-value
Model 1	0.8335	0.9986
Model 2	0.8383	0.9998

Source: Authors

The results presented in Table 5 show that for the first model, the number of backers is statistically significant at the level of 0.05 and is positive, while the project goal is significant at the level of 0.1 and the impact is negative. Consequently, hypotheses H1 and H3 are accepted.

Model 2 shows that only the number of backers is statistically significant at the level of 0.1, and the impact is positive just like in the first model. The impact of the project goal and duration is negative, but not statistically significant. According to the results of model 2, hypothesis H1 is accepted, while H2 and H3 are rejected due to a lack of statistical significance. The obtained results are in line with the results obtained by other authors who analysed

the success determinants of green crowdfunding campaigns, such as Predkiewicz and Kalinowska-Beszczyńska (2020), Corsini and Frey (2023) and Yang et al. (2019). In the research conducted by Predkiewicz and Kalinowska-Beszczyńska (2020), it is shown that the target amount has a negative impact on project success, and this corresponds to model 1 where the project goal impact is also negative. Corsini and Frey (2023) also performed logistic regression and confirmed the negative influence of the project goal and duration. In our model 2, the duration also has a negative impact, but it is not statistically significant. Cordova et al. (2015) used probit regression to model the success of technological campaigns and determined that the number of backers was a statistically significant variable that positively affects campaign success. In Herd et al. (2022), the regression analysis showed that a cumulative number of backers has a statistically significant influence on the raised amount.

Table 6: Logistic regression results

Variables	Model 1	Model 2
Number of backers	0.0955** (0.049)	0.11207* (0.066)
Project goal	-0.0003* (0.000)	-0.0003 (0.000)
Duration		-0.0034 (0.006)
Constant	-0.5109 (0.965)	-0.0957 (1.213)

Standard errors are presented in parentheses.

*p<0.05; **p<0.01.

Source: Authors

CONCLUSION AND IMPLICATIONS

Green crowdfunding is a type of crowdfunding oriented to projects/ideas that deal with the environment and sustainability. It is a field of financing that is in its first phases of development and research. It has still not been analysed in the CEE region. The development of this kind of financing is very important due to the fact that sustainable entrepreneurs encounter problems when it comes to obtaining the necessary capital from traditional sources and, also, from alternative sources of finance such as business angels, private equity,

venture capital, etc. Furthermore, the CEE region is characterized by a primary focus on bank financing, which is not suitable for such investments due to the high value of investment in sustainable projects (Yao, 2025) and higher costs and risks (Petruzzelli et al., 2019; Tenner and Hörisch, 2021; Yao, 2025). Consequently, policymakers should legally regulate different types of crowdfunding in order to reduce transaction costs and enable an unlimited spread of crowdfunding between countries. In addition, CEE countries that lag behind the Baltic countries should learn from their practice.

The results of the research show that the number of backers has a positive and statistically significant impact in both applied models. Namely, a higher number of backers increases the probability of campaign success. Regarding the variables of project goal and campaign duration, their impact is negative. That means that if the project goal is higher and the campaign duration is longer, the probability of campaign success is lower. In the first model, the project goal variable is statistically significant, whereby the project goal and campaign duration variables applied in model 2 are not statistically significant. The obtained results are in line with those obtained in the limited amount of research available on this topic.

This research has its limitations, which are primarily related to the number of green crowdfunding campaigns launched on Kickstarter in the CEE region. Namely, the number of undertaken campaigns affects the possibility of applying different kinds of success variables, as well as the application of various statistical models. Due to that, additional crowdfunding platforms could be considered, which would lead to a higher number of campaigns and an expansion of the research itself.

In future studies, we could investigate in more detail the influence of backers on the success of a campaign by considering the mean contribution variable (mean pledge size), which could be obtained by dividing the amount raised with the total number of backers. In addition, it would be interesting to explore the relation between the number of backers and campaign dynamics. This could be done by analysing the influence of early backers and late backers on campaign success. Furthermore, future research could deal with the causal mechanisms explaining why the number of backers influences campaign success. The potential mechanisms that could be considered here include social proof (herd behaviour), increased campaign exposure, reduced perception of risk, etc.

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CYBERSECURITY RISK AND FINANCIAL REPORTING QUALITY IN THE EU

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Rapid digitalization, global connectivity and an increasing amount of big data on the internet have increased the risk of cybersecurity incidents. Cybersecurity risk can be viewed as the likelihood of loss related to technical infrastructure, use of technology or reputation as a result of a cyber incident or data breach. Due to the increasing exposure to cybersecurity risks on a global scale, cybersecurity has become an important topic for researchers and professionals. Cybersecurity incidents or breaches can be seen as direct evidence of deficiencies in internal controls, and weaknesses in internal controls in one area are likely to be related to other weaknesses in internal controls, such as low-level financial reporting quality or earnings management. Therefore, the main objective of our paper is to investigate the relationship between cybersecurity risk and financial reporting quality. Only a few prior studies have analyzed earnings management in companies with data breaches. These papers typically use a US sample of companies with data breaches, which is then compared to a control sample. Recent research suggests that cybersecurity incidents are associated with a higher probability of financial restatements in the year of the breach and a higher probability of earnings manipulations via real earnings management, but not via accrual-based earnings management. In addition, these incidents may lead to higher audit firm fees and improved audit quality in the two years following a breach. In contrast to prior work that focused

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only on data breaches, we examine both cybersecurity ratings, as well as data breach incidents, because if an incident did not occur, it does not necessarily prove a high quality of the cybersecurity system.

For the empirical study, we used a large sample of 2,328 listed companies from EU countries in the period 2022-2023. The estimated results suggest that companies affected by cybersecurity incidents have a significantly higher level of earnings management i.e., a lower level of financial reporting quality. However, the effect of cybersecurity rating on the level of earnings management is not statistically significant.

Keywords: *Cybersecurity risk, financial reporting quality, earnings management, data breach*

JEL classification: *M41; O30*

INTRODUCTION

The global monetary cost of cybercrime in 2020 was estimated at around USD 945 billion, or just over one percent of the global domestic product (GDP). Furthermore, this cost was quickly increasing, since it was estimated at approximately USD 600 billion in 2018 (Smith and Lostri, 2020). Rapid digitalization, global connectivity and a growing amount of big data on the internet have increased the risk of cybersecurity incidents and cybersecurity has become an important topic for both researchers and professionals. Cybersecurity risk can be defined as “risk of financial loss, disruption, or damage to the reputation due to cyber incident or data breach” (Florackis et al., 2023).

In this paper, we investigate the relationship between the level of cybersecurity and the level of financial reporting quality. Namely, a cybersecurity incident is direct evidence of deficiencies in internal controls. We, therefore, assume that these internal control weaknesses will have negative implications in other internal control areas, such as financial reporting control, and will consequently lead to a lower level of financial reporting quality. Lawrence et al. (2018) state that there are two main reasons why weaknesses in operational controls are related to weaknesses in financial reporting controls: both operating and financial reporting systems depend on mutual controls, and weakness in one control area may indicate management’s general commitment to making a high-quality internal control system.

Despite the extensive previous research on cybersecurity, only a few studies have examined its relation to financial reporting quality. These papers typi-

cally use a US sample of companies with breaches, which is then compared to a control sample. The data set with breached companies is very unbalanced and contains a small number of companies with cybersecurity incidents. In addition, focusing on companies who have had a data breach can lead to selection bias, because if a cybersecurity incident did not occur, it does not necessarily prove a higher quality of the cybersecurity system (Slapničar et al., 2022). It is, therefore, critical to focus on the cybersecurity level rather than on a data breach incident. Finally, empirical findings on the impact of cybersecurity incidents on financial reporting quality are mixed. Some studies provide evidence that breached companies have a lower level of financial reporting quality in the years following the data breach (Lawrence et al., 2018), while other papers document that security breaches do not affect earnings management (Babo, 2022), or even increase the level of financial reporting quality (Rosati et al., 2020).

Our study seeks to contribute to the existing literature on the relationship between cybersecurity and financial reporting quality by examining cybersecurity ratings, as well as data breach incidents, because if an incident did not occur, it does not necessarily prove a high quality of the cybersecurity system. In this way, we can address the issues of selection bias and the small number of companies with cybersecurity incidents. Also, in contrast to the previous studies that typically use a US sample, we provide empirical insight into the cybersecurity level of EU listed companies.

We investigate the relationship between the level of cybersecurity and financial reporting quality by using a large sample of 2,328 listed companies from EU countries in the period from 2022 to 2023. The estimated results suggest that companies affected by cybersecurity incidents have a significantly higher level of earnings management, i.e. a lower level of financial reporting quality. However, the effect of cybersecurity rating on earnings management is not statistically significant.

The rest of the paper is organized as follows: the next section presents the theoretical background and discusses previous literature, section 3 outlines the research design and describes the sample, section 4 presents the results of the empirical analysis, while section 5 concludes the paper.

LITERATURE REVIEW AND THEORETICAL BACKGROUND

In recent years, there has been extensive research related to cybersecurity issues, especially after the EU and US market regulators adopted new rules regarding cybersecurity disclosure. The US Securities and Exchange Commis-

sion (SEC) has recognized the growing concern of cybersecurity risk. Consequently, in 2011 and 2018 the SEC issued a guidance to support companies in preparing disclosures concerning cybersecurity risks and incidents (SEC, 2011; SEC, 2018; Babo, 2022). Furthermore, with the aim of enhancing and standardizing disclosures concerning cybersecurity risk management and cybersecurity incidents, the SEC adopted new rules in 2023, assuming that this information may be relevant to investors (SEC, 2023). SEC Chairman Gary Gensler emphasized as follows: “Whether a company loses a factory in a fire or millions of files in a cybersecurity incident, it may be material to investors”. The first EU law on cybersecurity was implemented in 2016 in order to reach a common level of cybersecurity of information systems in the EU. The new NIS2 Directive became effective in 2023 and it strengthens cybersecurity requirements for companies in industries that are essential for the economy and the society, i.e. digital services, electronic communications services, transport waste management, health, energy, etc. (European Commission Press Release, 2024).

These new regulative requirements have led to a quick growth in cybersecurity disclosures in companies, and consequently to an increase in the number of research studies on this topic. Despite the rapid increase in the number of research papers on cybersecurity, there are only a few studies examining its relation to financial reporting quality. Lawrence et al. (2018) used an index based on data breaches and financial statements of US listed companies to indicate operational control risk and to prove that the operational control weakness can be used as a signal for potential financial reporting control weaknesses. They found evidence of a positive relation between operational control weaknesses and future restatements, the amount of audit fees and SEC comment letters. Babo (2022) also analyzed a sample of US public companies to find evidence of whether the companies that suffered damages caused by a cybersecurity incident took the chance to manipulate earnings to recover damages. The results showed that cybersecurity incidents do not have an effect on the level of earnings management. Rosati et al. (2022) empirically assessed the implications of data breaches on the level of audit quality for a large sample of US companies. They used a difference-in-difference statistical methodology based on a matched sample of companies with and without cybersecurity incidents and found no evidence that cybersecurity incidents have negative implications on the level of audit quality. On the contrary, they documented positive effects on financial reporting quality indicators. They assume that, if audit firms perceive cybersecurity incidents as signs of control weaknesses, they will increase their audit effort, and this will consequently lead to a higher level of audit quality. Jin et al. (2023) investigated whether banks’ earnings manage-

ment can predict a future cyber attack. They found that earnings management through discretionary loan loss provisions is positively associated with future cyber attacks, and banks use less earnings management after such incidents. Finally, Liu (2024) documented that auditing can decrease the probability of cyber incidents. There are two main mechanisms by which auditors can help prevent cyber incidents: the provision of relative information and incentives for internal controls.

To summarize, previous literature typically used US data on cyber incidents. Data sets with regard to breached companies are usually very unbalanced, containing a small number of companies with cybersecurity incidents. Finally, these data sets generally suffer from selection bias, because if a cyber incident did not occur, it does not prove that the firm's cybersecurity system is at a higher level than that of a firm that experienced a cyber incident.

Our paper adds to the literature by analyzing not only cybersecurity incidents, but also the level of cybersecurity rating and its impact on financial reporting quality for all listed companies. Based on the presented theoretical background, we assume that companies with a lower level of cybersecurity rating or with experienced cyber incidents in the last two years will have a lower level of financial reporting quality.

RESEARCH DESIGN AND SAMPLE SELECTION

MODEL AND VARIABLE MEASUREMENT

In order to test whether cybersecurity risk is related to financial reporting quality, we used a large sample of EU listed companies in the period from 2022 to 2023, and adopted a standard linear regression methodology.

Our dependent variable represents the level of earnings management or the level of financial reporting quality by estimating cross-sectional discretionary accruals from the modified Jones model (Dechow et al., 1995). Although accrual-based models have been extensively criticized (e.g., Hribar and Nichols, 2007; Gerakos, 2012; Liu and Wysocki, 2017; Chen et al., 2018; Jackson, 2018), they are still commonly used as evidence of earnings management. Namely, earnings represent the sum of accruals and operating cash flows, and extant previous literature provided evidence that managers primarily manipulate earnings *via* the accrual component of earnings, since it is easier and cheaper than *via* cash flows (Mendes et al., 2012). The main intention of accrual quality research is to separate the accruals that result from the company's fundamen-

tal business process from the abnormal, discretionary accruals that are due to intentional or accidental accounting errors. A higher proportion of the discretionary accrual component in earnings implies their lower quality.

We estimated the cross-sectional discretionary accruals using the modified Jones model (Dechow et al., 1995) in two stages:

$$\begin{aligned} ACC_{ijt} / TA_{ijt-1} = & \beta_{0jt} \left(1 / TA_{ijt-1} \right) + \beta_{1jt} \left(\Delta REV_{ijt} / TA_{ijt-1} \right) + \\ & + \beta_{2jt} (GPPE_{ijt} / TA_{ijt-1}) + \varepsilon_{it} \end{aligned} \quad (1)$$

$$\begin{aligned} DACC_{ijt} = ACC_{ijt} / TA_{ijt-1} - & \left[\hat{\beta}_{0jt} \left(1 / TA_{ijt-1} \right) + \hat{\beta}_{1jt} \left(\Delta REV_{ijt} / TA_{ijt-1} \right) + \right. \\ & \left. + \hat{\beta}_{2jt} (GPPE_{ijt} / TA_{ijt-1}) \right] \end{aligned} \quad (2)$$

where the subscript i represents each company in the industry-year estimation portfolios j by two-digit SIC codes, ACC is total accruals, TA is total assets at the beginning of the year, ΔREV is the change in revenue, GPPE is property, plant and equipment, and DACC is discretionary accrual component. At least 10 observations are required for each industry portfolio.

Finally, we used the absolute value of DACC (*Abs_dac*) as an earnings management proxy, where higher values of *Abs_dac* represent a higher likelihood of earnings management, i.e. lower financial reporting quality.

Our main explanatory variables are cyber-security risk proxies: Cyber rating, Cyber incidents dummy (*Inc*) or Difference between cyber-security rating and industry average (*Cyber_diff*).

The measurement of Cyber rating variable is based on BitSight cybersecurity rating methodology (BitSight, 2024). BitSight security ratings are calculated based on data from over 100 different sources and they include 25 risk vectors that are grouped into three main categories of security controls: compromised systems (27% weight), user behavior (2.5% weight), and diligence (70.5% weight). Compromised Systems analyses if devices in a company's network show symptoms of malicious or unwanted software (botnet infections, potentially exploited systems, unsolicited communications, spam propagation, malware servers). User behavior reflects how often employees are observed engaging in potentially risky behaviors (File Sharing) and Diligence analyses show how effective a company is in following security best practices and proactively defending against threats (Network Services; Software Assets; Application Security; Email Security; Information Exposure). BitSight security rating is size-adjusted in order for the ratings to be comparable between large and small companies. The distribution of security ratings is on a scale from

250 to 900, where 250 is the lowest measure of security performance and 900 is the highest. Rating values from 250 to 639 are classified as Basic level of cyber security; values from 640 to 739 are Intermediate; and values from 740 to 900 represent the Advanced level of cyber security systems (more information on BitSight cybersecurity ratings is available at www.bitsight.com/security-ratings). Beside the Cyber rating variable, we also use two additional cyber-security risk proxies: Cyber incidents dummy (*Inc*) and Difference between cyber-security rating and industry average (*Cyber_diff*). A binary variable (*Inc*) measures the occurrence of security incidents and it equals one if an incident was recorded in the last two years and zero otherwise.

We included several different variables as control variables: Return on assets (ROA); Solvency ratio (SR); Size; Current ratio (CR) and Industry 2-digit SIC code dummy variable. Variable definitions are presented in Table 1.

Table 1: Variable description

Variables	Description
Cyber Rating	BitSight Cybersecurity rating on a scale from 250 to 900, where 250 is the lowest measure of cyber security and 900 is the highest.
Cyber_diff	The difference between cyber-security rating and industry average.
Inc	The binary variable for security incidents equals 1 if an incident was recorded in the last two years and zero otherwise.
Abs_dac	The absolute value of cross-sectional discretionary accruals using the modified Jones model (Dechow et al., 1995).
Size	The natural logarithm of total assets.
ROA	Return on assets, net income scaled by average total assets.
SR	Solvency ratio, shareholders' funds divided by total assets.
CR	Current ratio, current assets divided by current liabilities.

Source: Authors' own work (2024)

Finally, in order to test whether earnings management is associated with cybersecurity risk, we estimated the following traditional OLS regression model:

$$\begin{aligned}
 \text{Abs\_dac}_{it} = & \beta_0 + \beta_1 \text{Cyber\_risk}_{it} + \beta_2 \text{SR}_{it} + \beta_3 \text{Size}_{it} + \\
 & + \beta_4 \text{ROA}_{it} + \beta_5 \text{CR}_{it} + \sum \beta \text{Industries} + e_{it}
 \end{aligned}
 \tag{3}$$

where Cyber_risk variables are *Cyber rating*, Cyber incidents dummy (*Inc*), and Difference between cybersecurity rating and industry average (*Cyber_diff*); *Industries* is the 2-digit SIC code binary variable; and definitions of all other variables are presented in Table 1.

SAMPLE

We gathered the data necessary for conducting the research from the Orbis Europe Database. Our sample is restricted to active, publicly listed companies from EU countries that have available accounts for the years 2021, 2022 and 2023, that apply IFRS standards, and that have available cyber risk data. The final sample consists of 2,328 companies. We analyzed the impact of cybersecurity risk on the level of earnings management in the period 2022-2023, however the data from the previous year is required in order to calculate all the variables in the model.

Table 2 provides the descriptive statistics for the numerical variables used in our analysis. The results show that, on average, companies in the sample have an intermediate level of cybersecurity rating (mean value of 694.16), and their cybersecurity rating is on average lower than the industry’s mean rating (mean value of -31.29).

Table 2: Descriptive statistics

Vari- ables	Obs	Mean	Std. Dev.	Min	Max	p1	p99	Skew.	Kurt.
Cyber rating	1775	694.163	70.469	330	810	440	790	-1.275	5.632
Cyber_ diff	1314	-31.294	67.558	-350	150	-230	80	-.809	4.010
Abs_ dac	3595	0.055	0.059	0	0.400	0.001	0.297	2.192	8.784
Size	3595	19.963	2.315	13.489	26.422	15.117	25.424	0.179	2.531
ROA	3564	2.268	14.86	-98.875	85.123	-62.05	29.231	-2.26	14.472
SR	3584	43.97	23.353	-98.245	99.94	-37.72	91.981	-0.886	6.420
CR	3594	1.986	3.169	0.021	97.333	0.138	11.175	15.09	350.442

See Table 1 for variable definitions.

Source: Authors’ own work (2024)

RESULTS

In the first part of the empirical research, we performed a univariate statistical analysis of the differences in the level of earnings management between companies with different categories of cybersecurity rating, and between breached and non-breached companies. Table 3 presents the results of the

ANOVA test for analyzing differences in the mean values of earnings management (*Abs_dac*) between three categories of cyber risk rating.

Table 3: Differences in the level of earnings management for cybersecurity categories (ANOVA test)

Cyber rating (cat.)	N	Mean Abs_dac	Std. Dev.	F-test	P-value
Basic	644	0.047	0.051	10.99	0.000
Intermediate	1,801	0.054	0.058		
Advanced	1,127	0.061	0.065		
Total	3,572	0.055	0.059		

See Table 1 for variable definitions.

Source: Authors' own work (2024)

The ANOVA results indicate that companies with a higher level of cybersecurity also have a higher level of earnings management (i.e. lower quality of financial reporting), which is contrary to our predictions. However, the ANOVA test does not account for the impact of other omitted (control) variables on earnings management. It is, therefore, necessary to perform a regression analysis with control variables so as to derive conclusions regarding the relationship between the cybersecurity rating and earnings management.

Table 4 presents the results of t-test statistics on differences in earnings management (*Abs_dac*) between companies with and without reported cybersecurity incidents. The results suggest that companies with cybersecurity incidents have a significantly higher level of earnings management (i.e. lower level of financial reporting quality), as predicted. However, similar to other previous studies on cybersecurity incidents, there is only a small number of companies that reported cybersecurity incidents in 2022 and 2023 (only 28 companies).

Table 4: Differences in the level of earnings management for companies with and without cybersecurity incidents

Variable	N (no Inc)	N (Inc)	Mean (no Inc)	Mean (Inc)	dif	t value	p value
Abs_dac	3567	28	0.055	0.077	-0.022	-2.000	0.044

See Table 1 for variable definitions.

Source: Authors' own work (2024)

We also conducted a correlation analysis to get insight into relationships between the variables and to check whether there is a risk of multicollinearity between the variables in our regression models (Table 5).

Table 5: Pearson correlation matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Cyber_Rating	1.000						
(2) Cyber_diff	0.974*	1.000					
(3) Abs_dac	0.101*	0.100*	1.000				
(4) Size	-0.239*	-0.214*	-0.263*	1.000			
(5) ROA	-0.091*	-0.093*	-0.166*	0.228*	1.000		
(6) SR	0.099*	0.107*	-0.070*	-0.111*	0.262*	1.000	
(7) CR	0.092*	0.079*	0.038*	-0.133*	0.034*	0.351*	1.000

See Table 1 for variable definitions.

* $p < 0.05$

Source: Authors' own work (2024)

Pearson's correlation coefficients indicate significant positive relations between the level of earnings management (*Abs_dac*) and both numerical cybersecurity risk variables: *Cyber rating*, and Difference between cybersecurity rating and industry average (*Cyber_diff*). The highest value of correlation coefficients is between these two proxies of cybersecurity risk, because they are both derived from the same indicator. However, each cybersecurity risk proxy is used separately in different regression models, so there is no risk of multicollinearity between these variables. Other correlation coefficients do not show presence of any strong correlation that could lead to a serious multicollinearity issue.

Finally, we estimated the parameters of the linear regression model from equation 3. Our dependent variable is the level of earnings management (*Abs_dac*) measured by the absolute value of cross-sectional discretionary accruals using the modified-Jones model (Dechow et al., 1995). Our cybersecurity variable is one of the following for each model: Cyber incidents dummy, *Inc* (model 1); Difference between cybersecurity rating and industry average, *Cyber_diff* (model 2); and *Cyber rating* (model 3). All other control variables are the same for all three models. The results are reported in Table 6.

Table 6: Regression results

	Expected sign	(1)	(2)	(3)
		Abs_dac	Abs_dac	Abs_dac
Inc	+	0.02992** (0.01067)		
SR		-0.00019** (0.00005)	-0.00009 (0.00007)	-0.00013* (0.00006)
CR		0.00065* (0.00031)	0.00047 (0.00047)	0.00049 (0.00043)
ROA		-0.00033** (0.00007)	-0.00037** (0.00012)	-0.00041** (0.0001)
Size		-0.00609** (0.00045)	-0.00519** (0.00077)	-0.00544** (0.00064)
Cyber_diff	-		0.00002 (0.00002)	
Cyber_Rating	-			0.00003 (0.00002)
Constant		0.17706** (0.01378)	0.13646** (0.02208)	0.11673** (0.02482)
Observations		3555	1303	1758
R-squared		0.11952	0.14338	0.13717

Standard errors are presented in parentheses. Industry dummies are included in all models. See Table 1 for variable definitions.

** $p < 0.01$, * $p < 0.05$

Source: Authors' own work (2024)

Regression results indicate that all models are overall statistically significant and have the appropriate level of explanatory power (R^2 from 11.95% to 14.34%). Industry fixed effects are included in all the models. The results suggest that companies affected by cybersecurity incidents have a significantly higher level of earnings management, i.e. lower level of financial reporting quality. However, the effect of the cybersecurity rating or the difference between the cybersecurity rating and the industry average (*Cyber_diff*) on earnings management are not statistically significant.

CONCLUSION

Due to an increasing exposure to cybersecurity risks on a global scale, cybersecurity has become an important topic for researchers and professionals. In contrast to prior work that focused only on the impact of data breaches on financial reporting quality, we examined both the cybersecurity ratings and the data breach incidents. Namely, if a cyber incident did not occur, it does not prove that the cybersecurity system of the firm is at a higher level than that of a firm that has experienced a cyber incident. In this way, we can accommodate the issue of selection bias. Also, in contrast to the previous studies that typically use a US sample, we provided an empirical insight into the cybersecurity level of EU listed companies.

The estimated results suggest that EU companies affected by cybersecurity incidents have a significantly lower level of financial reporting quality, i.e. a higher level of earnings management as we predicted, but the effect of the cybersecurity rating on earnings management is not statistically significant. We assumed that internal control weaknesses related to cybersecurity would have negative implications in other internal control areas, such as financial reporting control, and would consequently result in a lower level of financial reporting quality.

Our study is also subject to several limitations. We performed the analysis only on EU listed companies and there was a small number of companies with cyber incidents, which limits the generalization of our conclusions. In addition, we used only one indicator for financial reporting quality, while there are many other measures and dimensions of financial reporting quality. Furthermore, although the majority of previous studies analyze the effect of cyber-attacks on earnings management (Babo, 2022; Rosati et al., 2022; Lawrence et al., 2018), the possibility of reverse causality should also be considered. Specifically, earnings management could potentially be associated with future cyber-attacks. Nevertheless, our results and conclusions should have important implications for researchers, auditors, regulators and managers.

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THE PREDICTIVE NATURE OF ESG FOR BANK PERFORMANCE: COMPOSITE VERSUS COMPONENT SCORES

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Environmental, social, and governance (ESG) practices are shifting the banking landscape from traditional to sustainable. This emerging trend has recently created a global interest in assessing the ESG–bank performance relationship. Preliminary evidence about the financial benefits of such and similar ESG efforts in the banking industry is mixed: positive, negative, or insignificant. Moreover, the existing studies mainly offer only partial (country-specific or ESG pillar-specific) insights. Therefore, our research used resource-based theory and stakeholder theory with an aim to address and explore the conflicting relationships between ESG and bank performance across Europe. Both the composite (aggregated) and component-wise (disaggregated) approach were applied. The study sample consisted of 118 European commercial banks listed by ESG Book, encountering 590 observations from a five-year perspective (2019-2023). Following the Hausman test results, we applied a fixed-effect panel regression technique to reveal a weak negative, yet significant relationship between overall (composite) banks' ESG ratings and their accounting-based performance measures (i.e., return on assets and return on equity). Further component-wise analyses indicated a differing statistical relevance of each ESG pillar. Specifically, we found significant negative

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relationships between the environmental pillar and return on assets, as well as between the social pillar and return on equity. All other ESG pillar–bank performance relationships were insignificant, therefore strongly indicating a non-significant role of the governance pillar for achieving banks’ return on assets and return on equity. The present research offers a two-fold theoretical contribution. First, it sheds light on the contextual nature of the relationship between ESG and bank performance. The heterogeneity of existing studies is conceived as a reason why reported ESG–performance relationships differ substantially across studies. Second, the present findings unambiguously communicate that ESG is a complex phenomenon that requires dancing between “zoom-in” and “zoom-out” perspectives to specify performance consequences in the banking industry. From a practical standpoint, we would like to alert bank and investment managers that ESG requires critical thinking.

Keywords: *ESG, bank financial performance, panel regression, composite versus component approach*

JEL classification: *C23, G15, G21, M14, O16*

INTRODUCTION

Environmental, social, and governance (ESG) practices are shifting the banking landscape from traditional to sustainable (Riegler, 2023; Venanzi & Matteucci, 2022). No bank is an ‘island’ and cannot remain ignorant in the age of ESG. The leading banks are forerunners who increasingly designate ESG controllers, invest in ESG disclosures, and introduce new procedures and tools in order to enhance ESG strategies (Arnold, Torrente, Horsley, Wagner, & Neykova, 2023). As a result, similar to extensive general evidence on the ESG policy–corporate performance link (Friede, Busch, & Bassen, 2015), we would expect to find a positive relationship in the banking industry. However, preliminary evidence about the financial benefits of such and similar ESG efforts in the banking industry are mixed: positive (e.g., Gangi, Meles, D’Angelo & Daniele, 2019; Shakil, Mahmood, Tasnia & Munim, 2019), negative (e.g., Jo, Kim & Park, 2015; Peni & Vähämaa, 2012) or insignificant (e.g., Harkin, Mare, & Crook, 2020; Maxfield, Wang & Magaldi de Sousa, 2018). Moreover, the existing studies primarily offer only partial (country-specific or ESG pillar-specific) insights.

Our research, therefore, aims to address and explore the relationship between ESG and bank performance across Europe, both compositely and com-

ponent-wise. The sample consisted of 118 European commercial banks listed by ESG Book (<https://www.esgbook.com>), a recently established rating agency that provides transparent and comparable ESG data. We examined each bank within their ESG database from a five-year perspective (2019-2023) and encountered 590 observations. A fixed-effect panel regression technique enabled us to analyze the evolution of ESG and accounting-based bank performance (i.e., return on assets and equity) over time (Baltagi, 2005).

Our study unambiguously communicates that ESG is a complex phenomenon that requires dancing between “zoom-in” and “zoom-out” perspectives to specify performance consequences in the banking industry. Such an approach enabled us to realize that ESG banking activities in Europe are not a gold mine – depending on their type and context, they could be inefficient and non-profitable.

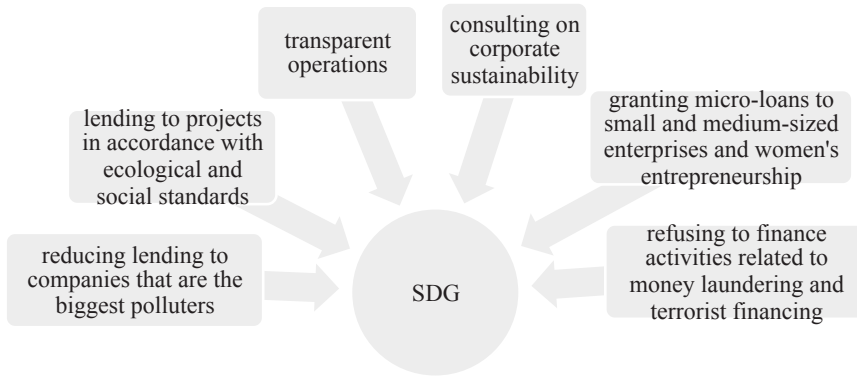
THEORY AND HYPOTHESES

ESG IN BANKING

The banking sector’s sustainability is becoming crucial for a healthy economy (Aras, Tezcan, & Kutlu Furtuna, 2018). The European banking sector is a flagship considered environmentally and socially responsible (Jeucken & Bouma, 2017). European banks are not only devoted to reducing their carbon footprint – they ensure financial support for sustainable economic growth, re-direct private capital towards sustainable activities (Houston & Shan, 2022; Torre Olmo, Cantero Saiz & Sanfilippo Azofra, 2021), and offer sustainable-focused products and services (Mijs, 2021).

Moreover, European banks are increasingly harmonizing their operations with the UN’s Sustainable Development Goals and the Financial Initiative of the United Nations for the Environment, as well as complying with and supporting the European Regulatory Framework in achieving carbon neutrality by 2050. Examples of banks’ contributions to achieving sustainable development goals are shown in Figure 1.

Figure 1: Bank contributions to the achievement of sustainable development goals



Source: Authors

ESG AND BANK PERFORMANCE: THEORETICAL AND PRACTICAL CONTRADICTIONS

Although there is surmounting and consistent (general) evidence about the positive relationship between ESG policies and corporate performance (see Friede et al., 2015), we are still inconclusive about the performance consequences of ESG in the banking sector. Both theory and practice create confusion and contradiction.

Resource-based theory and stakeholder theory explain and support the positive nature of the focal relationship. The former views ESG as a resource that improves financial performance (Zhou, Liu & Luo, 2022) and creates a sustainable competitive advantage (Huarng & Yu, 2024). The latter suggests that a positive outcome can be achieved through ESG engagement and maximizing the interests of different stakeholder groups (Jo & Harjoto, 2011; Sain & Kashiramka, 2024). The empirical evidence supported these assumptions (e.g., Buallay, 2018; Akdogan, Selimoglu & Turkcan, 2020; Bischof, Bourdier, Gassmann, Wackerbeck & Marek, 2021), although a few studies indicated that the positive effect holds up to a certain level of ESG (e.g., El Khoury, Nasrallah & Alareeni, 2023).

However, Friedman's neoclassic theory (2007) and trade-off theory state the opposite: ESG practices lead to opportunity loss (Sain & Kashiramka, 2024), increase costs, harm bank performance, and impair competitive advantage (Menicucci & Paolucci, 2023). Galant & Cadez (2017) further argued that ESG standards demand that banks spend more financial resources to meet

social and environmental goals. Moreover, Di Tommaso and Thornton (2020) evidenced how ESG reduced bank value in a sample of European banks. Yuen, Ngo, Le and Ho (2022) noted a similar negative impact, suggesting a U-shaped relationship between ESG and bank performance during the COVID-19 pandemic. Following all of the above-mentioned and because there is no consensus reached in the literature, we defined the following conflicting hypotheses:

H1a: *ESG is positively related to accounting-based measures of bank performance.*

H1b: *ESG is negatively related to accounting-based measures of bank performance.*

THE ROLE OF THE ENVIRONMENTAL PILLAR IN BANK PERFORMANCE

The environmental pillar of ESG focuses on protecting the environment and scarce natural resources. The motive of achieving ecological goals drives banks to pursue this green perspective and introduce ecological criteria for crediting decisions (e.g., preservation of biodiversity, waste management and pollution, or usage of renewable energy sources) or carbon footprint reduction (Zimmermann, 2019).

According to the stakeholder and resource-based theories, environmental practices should positively affect bank performance (El Khoury et al., 2023). Indeed, green-based lending policies and the supply of climate products or other socially responsible saving instruments signal a bank's commitment to environmental policies (Gangi et al., 2019). On the other hand, El Khoury et al. (2023) argued that environmental investment might result in additional financial costs, thus highlighting a potential cost-benefit dilemma. However, the existing research showed that the environmental pillar positively predicts a bank's ROE (Shakil et al., 2019; Nizam, Ng, Dewandaru, Nagayev & Nkoba, 2019). Therefore, we assume the following:

H2: *Environmental aspects are positively related to the accounting-based financial performance of banks.*

THE ROLE OF THE SOCIAL PILLAR IN BANK PERFORMANCE

The social pillar of ESG deals with societal and work environment issues such as working conditions, child labor, equal opportunities, social inclusion, protection of human rights, gender-based violence and harassment, and investment in

the local community. Banks pursuing the social aspect are particularly interested in social justice and cohesion and prefer using social criteria as a prerequisite for credit approval (Zimmermann, 2019). Moreover, they are prone to finance non-profitable organizations and offer financial products and services to more vulnerable and/or excluded social groups (Fatemi, Fooladi & Tehranian, 2015).

According to the stakeholder theory, social responsibility promotes equity, justice, and societal well-being (Ngamvilaikorn, Lhaopadchan & Treepongkaruna, 2024). Specifically, it improves banks' long-term financial performance and market position (Velte, 2017), public perception (Gangi et al., 2019), and reputation (Buallay, Fadel, Alajmi & Saudagaran, 2021). Therefore, we propose the following social impact hypothesis:

H3: The social pillar is positively related to the accounting-based measures of bank performance.

THE ROLE OF THE GOVERNANCE PILLAR IN BANK PERFORMANCE

The governance pillar of ESG primarily focuses on corporate governance structure and mechanisms (i.e., decision-making processes). In particular, it handles issues related to the purpose and value proposition, ethics in business, compensation structure, adequacy of internal controls, shareholder rights, bribery and corruption, salary adequacy, diversity and independence of board and supervisory board members, reporting and transparency, risk management and others (IFC, 2021). Governance in the banking industry is crucial, as any failure in this regard will have a cascading effect on the economy (Sain & Kashiramka, 2024).

A sound governance system should contribute to higher performance (e.g., Carter, Simkins & Simpson, 2003; Harkin et al., 2020). In this regard, several studies demonstrated that effective corporate governance increased financial performance (e.g., Esteban-Sanchez, de la Cuesta-Gonzalez & Paredes-Gazquez, 2017) by boosting reputation and mitigating mismanagement (Zehri & Zgarni, 2020). However, Shakil et al. (2019) found no association, and Ngamvilaikorn et al. (2024) reported that banks with larger board sizes, more female directors, and higher levels of corporate governance commitments underperform. Mixed findings imply that the governance pillar–bank performance link remains controversial. Since few studies supported the positive role of banks' corporate governance practices, we hypothesize as follows:

H4: The governance pillar is positively related to the accounting-based measures of bank performance.

METHOD

SAMPLE

ESG rating agencies systematically analyze the sustainable practices of organizations (including banks), thus offering critical information for investment and financial decisions (Bissoondoyal-Bheenick, Bennett, Lehnherr & Zhong, 2024). Beyond several prominent major rating agencies (e.g., Sustainalytics, Moody, S&P Global, MSCI) whose ratings diverge substantially (see Berg, Kölbel & Rigobon, 2022), we used transparent and free-of-charge available ESG Book data-driven assessment. Their ESG Performance Score relies on a sector-specific scoring model based on publicly available bank data (ESG Book, 2023).

Our sample consisted of 118 European commercial banks. The rating agency (i.e., ESG Book) provided ESG (i.e., composite and component) scores for each bank. We examined the annual scores within a five-year time frame (2019-2023). However, for 52.5% of banks, we did not have complete data (i.e. data for the period 2019-2021 were missing). We, therefore, analyzed listwise (a listwise deletion strategy applied) and imputed (with the linear trend at point) datasets.

MEASURES

The combined indicators of environmental (Env), social (Soc), and governance (Gov) pillars have been commonly used in previous sustainable banking studies (e.g., Buallay et al., 2021; Esteban-Sanchez et al., 2017) to represent a comprehensive scoring of a bank's ESG maturity. We followed the same path and used the ESG Performance Score as our primary explanatory variable. This composite index covers 26 categories (structured into five general issue categories) and 202 metrics, which are transformed to a uniform scale (0 – 100) using a relative scoring approach (ESG Book, 2023). Besides ESG-specific (i.e., environmental, social capital, and leadership and governance) issue categories, the ESG Book methodology covered two additional general categories we did not address in our research: business model and innovation and human capital.

A component approach followed the composite one in order to examine how each ESG pillar contributes to a bank's financial performance. The environmental pillar included the following categories: Air Quality, Ecological Im-

pacts, Energy Management, GHG Emissions, Waste and Hazardous Materials Management, and Water and Wastewater Management. The social pillar covered seven categories: Access and Affordability, Customer Privacy, Customer Welfare, Data Security, Human Rights and Community Relations, Product Quality and Safety, and Selling Practices and Product Labelling. The governance pillar included five categories: Business Ethics, Competitive Behavior, Critical Incident Risk Management, Management of the Legal and Regulatory Environment, and Systematic Risk Management. The rating agency calculated each category score as the average of the underlying transformed metrics (ESG Book, 2023).

Bank performance was our dependent (outcome) variable. We used accounting-based measures of return on assets (ROA) and return on equity (ROE) as common and well-accepted indicators of banking sector profitability (e.g., Bătae, Dragomir & Feleagă, 2021; Menicucci & Paolucci, 2023). ROA measures the profitability of total bank assets (operational performance) by dividing net income after taxes by the average total assets (Esteban-Sanchez et al., 2017). ROE represents the profitability of the bank investment equity (financial performance) by dividing net income after taxes by the average total equity (Nizam et al., 2019).

PROCEDURE

The longitudinal nature of data and corresponding research design enabled us to adopt a panel regression technique. Four regressor variables (i.e., ESG as a composite and E, S, and G as components) and two performance outcomes (i.e., ROA and ROE) yielded the following econometric models:

$$ROA_{i,t} = \beta_0 + \beta_1 ESG_{i,t} + \varepsilon_{i,t} \quad (1)$$

$$ROE_{i,t} = \beta_0 + \beta_1 ESG_{i,t} + \varepsilon_{i,t} \quad (2)$$

$$ROA_{i,t} = \beta_0 + \beta_1 Env_{i,t} + \varepsilon_{i,t} \quad (3)$$

$$ROE_{i,t} = \beta_0 + \beta_1 Env_{i,t} + \varepsilon_{i,t} \quad (4)$$

$$ROA_{i,t} = \beta_0 + \beta_1 Soc_{i,t} + \varepsilon_{i,t} \quad (5)$$

$$ROE_{i,t} = \beta_0 + \beta_1 Soc_{i,t} + \varepsilon_{i,t} \quad (6)$$

$$ROA_{i,t} = \beta_0 + \beta_1 Gov_{i,t} + \varepsilon_{i,t} \quad (7)$$

$$ROE_{i,t} = \beta_0 + \beta_1 Gov_{i,t} + \varepsilon_{i,t} \quad (8)$$

where ROA and ROE represent standalone dependent variables (i) in the year (t), while ESG, environmental (Env), social (Soc), and governance (Gov) are independent variables that indicate the level of bank sustainability (i) in the year (t).

The Hausman test was used to decide whether the fixed or random-effects model is applicable (Hausman, 1978). Since the p-values were consistently below .05 (indicating the high variation observed in ESG over time), we applied the fixed-effects regression. Thus, we analyzed the within-unit variation and assumed that the intercept is not random, where each bank is significantly different in terms of its base level on the outcome variable (El Khoury et al., 2023).

RESULTS

DESCRIPTIVES AND CORRELATIONS

The descriptive results (Table 1) show high variability in ESG composite scores, with a minimum of 31.30 and a maximum of 78.43. The governance pillar ($M = 59.87$, $SD = 11.89$) had the highest average, although differences across pillars were not substantial. Our sample consisted of good-performing European banks; the average values of ROA ($M = 1.29$, $SD = 2.64$) and ROE ($M = 10.40$, $SD = 11.16$) were above 1% and 10% (the generally accepted threshold values that separate successful banks from unsuccessful ones; Stojanović, 2022).

Table 1: Descriptive statistics of ESG and accounting-based performance scores

Variable	N	Mean	Std. Dev.	Min	Max
ESG	408	58.57	9.37	31.30	78.43
Environmental (Env)	414	58.29	13.57	35.71	90.08
Social (Soc)	414	57.94	12.76	29.57	90.09
Governance (Gov)	414	59.87	11.89	29.22	87.05
ROA	590	1.29	2.64	-4.10	34.20
ROE	590	10.40	11.16	-56.28	55.59

Source: Authors

Before running panel regression, we calculated bivariate Pearson correlations. The ESG pillars were mutually (positively) related in both samples (see Table 2). Interestingly, the environmental pillar had a stronger relationship with the governance pillar ($r = .512$, $p < .01$ for the listwise sample; $r = .505$, $p <$

.01 for the imputed sample) than with the social pillar ($r = .316, p < .01$ for the listwise sample; $r = .276, p < .01$ for the imputed sample). Composite ESG had a statistically significant negative relationship with bank performance scores ($r_{ROA} = -.123, p < .05$ and $r_{ROE} = -.167, p < .01$ in the listwise sample; $r_{ROA} = -.083, p < .05$ and $r_{ROE} = -.143, p < .01$ in the imputed sample). Similar negative relationships were uncovered between ESG pillars and bank performance scores, with the Social (Soc)–ROA and Environmental (Env)–ROE relationships being uncorrelated exceptions.

Table 2: Correlation matrix

Variable	ESG	Env	Soc	Gov	ROA	ROE
ESG	-	.696**	.750**	.744**	-.083*	-.143**
Environmental (Env)	.698**	-	.313**	.505**	-.122**	-.068
Social (Soc)	.753**	.316**	-	.276**	-.026	-.114**
Governance (Gov)	.752**	.512**	.294**	-	-.080	-.095*
ROA	-.123*	-.184**	-.041	-.117*	-	.430**
ROE	-.167**	-.082	-.139**	-.104*	.390**	-

Note: * $p < .05$; ** $p < .01$; Listwise sample (i.e., without missing values), $N = 408$ (below the diagonal), Imputed sample (with the linear trend at point), $N = 590$ (above the diagonal)

Source: Authors

PANEL REGRESSION RESULTS

We tested our hypotheses by running four sets of panel regression models. First, we noted that a composite ESG rating is weakly, yet consistently negatively and statistically, significantly related across samples to the return on assets ($B = -.028, SE = .011, p < .05$ for the listwise sample; $B = -.028, SE = .014, p < .05$ for the imputed sample) and the return on equity ($B = -.202, SE = .059, p < .01$ for the listwise sample; $B = -.205, SE = .058, p < .01$ for the imputed sample). In other words, the results showed that ESG is a negative predictor of bank performance, leading us to reject Hypothesis 1a and accept Hypothesis 1b.

Further component-wise analyses similarly revealed negative relationships between ESG pillars and bank performance outcomes. However, not all bivariate relationships were significant. Specifically, the environmental pillar had a negative and statistically significant relationship with ROA ($B = -.026, SE = .009, p < .01$ for the listwise sample, and $B = -.026, SE = .011, p < .05$ for the imputed sample), but not with ROE ($B = -.007, SE = .048, n.s.$ for the listwise

sample and $B = -.005$, $SE = .048$, n.s. for the imputed sample). Nevertheless, we had to reject Hypothesis 2, theoretically assuming a positive relationship.

In the case of the social pillar, we found just the opposite – there was a negative and statistically significant relationship between the social pillar and ROE ($B = -.097$, $SE = .046$, $p < .05$ for the listwise sample and $B = -.098$, $SE = .046$, $p < .05$ for the imputed sample). At the same time, this ESG pillar did not have an influence on ROA ($B = .004$, $SE = .009$, n.s. for the listwise sample, and $B = .004$, $SE = .011$, n.s. for the imputed sample), thus not providing support for Hypothesis 3. Finally, the governance pillar remained an insignificant predictor for both accounting-based bank performance measures, resulting in the rejection of Hypothesis 4.

Table 3: Panel regression with fixed effects

Parameter	ROA				ROE			
	Listwise sample		Imputed sample		Listwise sample		Imputed sample	
	B (SE)	p-value	B (SE)	p-value	B (SE)	p-value	B (SE)	p-value
<i>Component scores</i>								
Intercept	3.030 (.643)	.000	3.019 (.805)	.000	21.365 (3.431)	.000	20.824 (3.394)	.000
Environmental	-.026 (.009)	.004	-.026 (.011)	.020	-.007 (.048)	.882	-.005 (.048)	.910
Social	.004 (.009)	.484	.004 (.011)	.699	-.097 (.046)	.035	-.098 (.046)	.032
Governance	-.007 (.010)	.469	-.007 (.013)	.567	-.072 (.054)	.186	-.074 (.054)	.169
R ²	.034		.016		.024		.017	
<i>Composite score</i>								
Intercept	2.955 (.665)	.000	2.932 (.824)	.000	22.906 (3.507)	.000	22.387 (3.454)	.000
ESG	-.028 (.011)	.013	-.028 (.014)	.045	-.202 (.059)	.001	-.205 (.058)	.000
R ²	.015		.007		.028		.020	

Source: Authors

DISCUSSION AND CONCLUSION

The existing mixed evidence motivated us to conduct this quantitative panel data research. We applied a composite (aggregated) and a component (disaggregated) approach to studying European banks' ESG–bank performance relationship. Panel regression analyses with fixed effects using transparent five-year data (2019–2023) obtained by a novel rating agency (i.e., ESG Book) revealed a negative relationship between ESG (and ESG pillars) and accounting-based bank performance ratings (i.e., ROA and ROE).

THEORETICAL AND PRACTICAL IMPLICATIONS

The present study offers a twofold theoretical contribution. First, it sheds light on the contextual nature of the relationship between ESG and bank performance. Contrary to a decade-long mainstream belief about the positive performance consequences of introducing corporate ESG policies (see Friede et al., 2015), we found the opposite trend (i.e., inconclusive results) in sustainable banking. This further led us to double-check why banking sector findings are inconclusive (Nizam et al., 2019). In search of understanding, we realized that the heterogeneity of studies might influence the relationship. For instance, while positive ESG–bank performance relationships were reported from 2007 to 2016 (Buallay, 2018), Menicucci & Paolucci (2023) found that ESG as a composite index negatively affected bank performance in Italy from 2016 to 2020. Moreover, while Yuen et al. (2022) argued robust results in developed vs. developing countries, region- (e.g., El-Khoury et al., 2023) and country-specific studies (e.g., Menicucci & Paolucci, 2023) reported differing conclusions. Therefore, we suggest that researchers should be tentative and should (1) control for the geographical coverage of research, (2) consider the timeframe of the study, (3) acknowledge the divergent nature of ESG ratings (Berg et al., 2022), and (4) be aware of the performance measures used.

Second, our study unambiguously indicated the importance of disaggregating ESG into components and focusing on specific ESG pillar–performance relationships. Indeed, although combined and mainly presented as an integrative concept, ESG consists of differing practices that explain the overall ESG score differently (Billio, Fitzpatrick, Latino & Pelizzon, 2024). For instance, we found the role of the governance pillar to be non-significant, which differs from a concave relationship reported by El-Khoury et al. (2023) or a negative relationship presented by Buallay (2018). Similar discrepancies in findings

exist for the remaining two ESG pillars. We found significant negative relationships between the environmental pillar and return on assets, and between the social pillar and return on equity. The other two ESG pillar-performance relationships remained insignificant. Such differences emerge not only from divergent ESG ratings (Berg et al., 2022), but may call for additional disaggregation. Indeed, we should not forget that each ESG pillar is also an aggregate (a second-order factor) comprised of several metrics and indicators that might not necessarily align entirely (e.g., Meniucchi & Paolucci, 2023).

From a practical standpoint, the present research aims to keep bank and investment managers on alert. In line with a few others, our study communicates that ESG in short term or within a crisis is not always contributinal and requires critical thinking. Bank managers should not be conformists; ESG is on hype; it indeed represents a much-needed business practice. However, it is still worth questioning which aspects – pillars and metrics – of ESG (and to what extent) banks should implement within a particular context and timeframe. For instance, an eye-opening finding was offered by Menicucci and Paolucci (2023), who showed that only the indicator of emission and waste reductions (ENV_Em) is correlated with bank performance.

STUDY LIMITATIONS AND FUTURE RESEARCH

Our research is not without limitations. We used a single rating agency dataset (i.e., ESG Book) and observed a limited number of European banks within a particular time frame (i.e., COVID period; deterioration of the geopolitical situation). Future research should include multiple ratings from different providers (e.g., Refinitiv, S&P Global) and cover a representative sample of financial institutions in the long run (e.g., pre-COVID, COVID, and post-COVID periods). Additionally, one should consider that deteriorated geopolitical conditions are challenging for the dynamics of sustainable transition, which also might have impacted our results concerning the focal relationship.

Next, we should go beyond ROA and ROE and include diverse bank performance measures. For instance, observing risk-taking behavior (e.g., Di Tommaso & Thornton, 2020) in addition to financial (ROE, stock market returns), operational (ROA), or market (Tobin's Q) performance would be interesting.

On a related note, control variables should be observed to provide more robust insights for country-level (e.g., GDP growth, inflation, corruption) and institution-level (e.g., bank size, bank ESG strategy, capital adequacy ratio, liquid asset ratio) variables. For instance, Bătae et al. (2021) indicated that larger

banks, on average, record better results in the field of sustainability, which can be attributed to more significant resources and better operational capability that banks of this size possess compared to other smaller banks. We were not able to make such insights on our limited dataset.

To conclude, banks should integrate all aspects of ESG to support the transition to sustainability. The results of this research indicated that, regarding short-term financial performance, in order to increase it, the banks may consider adopting the highest-quality corporate governance requirements and reconsider the attention given to environmental and social aspects. Nevertheless, in the long run and in non-pandemic times, ESG is still preferable for combining economic results with sustainability development goals.

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REGULATING THE SHARING ECONOMY: CHALLENGES, IMPLICATIONS AND FAIRNESS - BASED CONCERNS

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The rapid development of the sharing economy in the past decade has attracted significant research attention. The sharing economy (SE) is a global phenomenon and the leading companies, such as Uber and Airbnb, have become highly profitable multinational businesses whose expansion has wider socioeconomic implications. Despite its growing importance, a lot is still unknown about the SE. Even the term “sharing economy” is in dispute, since prominent companies such as Uber and Airbnb do not necessarily involve any sharing. While there are numerous potential long-term benefits of SE arrangements, there are also various concerns surrounding the SE, including the sometimes underestimated fairness-based concerns such as those related to fairness of cooperation within SE ventures and to fairness of competition between sharing and traditional businesses. Such concerns call for effective and adequate regulatory action. The core problem is the lack of consensus on what would be an appropriate regulatory approach, or whether traditional forms of regulation are even suitable for diverse SE arrangements. Despite progress, policymakers are still struggling to develop appropriate guidelines. Regulating the SE is a challenging task since SE arrangements often do not align with traditional legal categories and frameworks. Conflicting stakeholder interests do not help either. Despite ongoing disagreements, there are reasons to hold that a one-size-fits-all regulatory approach may not be a satisfying regulatory

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solution given the diversity of SE models, businesses and activities. If restrictive, it may also impede further SE development and its beneficial potential. This paper argues that an appropriate regulatory scheme should thus be flexible and based on tier-based regulation which would be tied to the volume of transactions (activity), with more lenient regulation and requirements for smaller SE ventures and providers. It should also be fair and acceptable to all.

Keywords: *Sharing economy, regulation, externalities, gig labour, fairness*

JEL classification: *M20, L51, J81, J83*

INTRODUCTION

“At the core of the so-called sharing economy are freewheeling, innovation-obsessed, algorithm-driven companies that, by their very nature, resist regulation.” (Powers, 2016)

The underlying idea of SE is not new. Its historical roots can be traced back to personal exchanges and earlier barter economies. As societies and economies developed, the focus shifted from (resource) sharing to ownership, and sharing became limited to personal relationships and local communities. With the development of digital technologies (the Internet), transaction costs for sharing activities were drastically reduced, enabling the emergence of the contemporary SE. Initially driven by non-profit platforms, the SE developed into profitable business models, exemplified by Uber and Airbnb (Cheng, 2016). The SE has become a global phenomenon, expanding across countries and sectors (transportation, accommodation, finance, household services, etc.). Despite its increasing importance, a lot remains unknown about the SE and its long-term impact. Indeed, even the term “sharing economy” is subject to various debates. Despite much speculation on its potential long-term socio-economic benefits, the ongoing SE expansion raises various concerns regarding its negative impact on societies and individuals, including the somewhat underestimated fairness-based concerns. These concerns demand an appropriate regulatory response from governments, especially since prominent ventures such as Airbnb and Uber have developed into highly profitable multinational businesses, with wider societal implications. The core problem arises from the lack of agreement on what would be an appropriate regulatory approach to the

SE, and whether traditional forms of regulation are even suitable for diverse SE arrangements, given various regulatory challenges involved. Policymakers are still struggling to develop appropriate policy guidelines.

The main question of this paper refers to how diverse SE ventures should be regulated. Does the SE have a potential for effective self-regulation, or is robust political regulation required to adequately address its undesirable aspects? What would be an effective and fair regulatory scheme? The paper is structured as follows. The first part addresses the conceptual issues surrounding the SE. It also addresses the main advantages, disadvantages and prominent fairness-based concerns related to the SE. The next part examines the prominent challenges and difficulties in regulating the SE, followed by a comparative overview of different regulatory approaches and recent developments in the EU. The final part addresses the issue of what might be an effective and fair regulatory scheme for the SE in light of the ongoing disagreements.

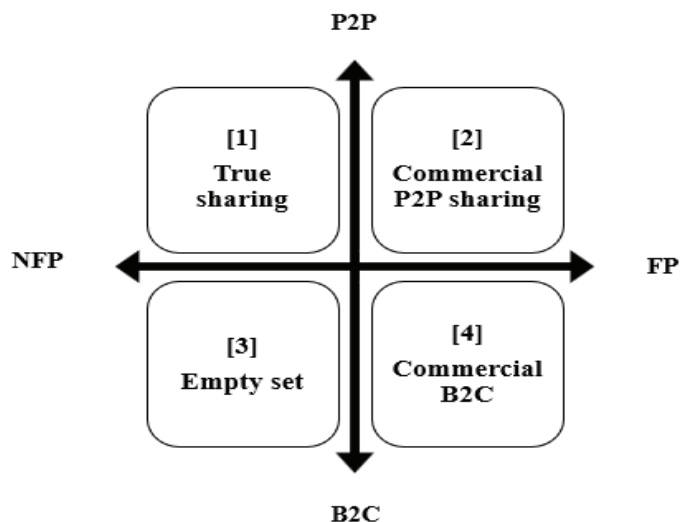
THE SHARING ECONOMY

There is no standard definition of the SE, with existing definitions varying significantly, and even contradicting one another (Grybaite et al., 2022; Ježova, 2020; Mont et al., 2020; Rodrigues, 2019; Munkoe, 2017; Frenken & Schor, 2017). Confusion also arises because activities and ventures commonly associated with the SE have been labelled by different names, i.e. peer-to-peer economy, collaborative economy, platform or digital economy, gig or on-demand economy, and access economy. The SE remains ambiguous (Ahsan, 2020), with the term applied to diverse models, ventures and activities ranging from open-source communities and non-profit platforms to profitable global companies. There is little consensus on the practices and ventures comprising the SE. Even the term “sharing economy” is in dispute since enterprises such as Uber and Airbnb do not involve any “sharing”. Belk (2014) argues that the term does not distinguish between “true” and “pseudo” or “commercial” sharing. True sharing involves temporary access, without ownership, compensation or fees. Major commercial platforms labelled as “sharing economy” do not belong there. Most definitions still recognize both non-commercial and commercial sharing (Kirchner and Schüßler, 2020).

Based on a comprehensive literature review, Schlagwein, Schoder & Spindeldreher (2020: 829) developed a consolidated definition according to which SE is a peer-to-peer model enabled by IT technology, used for non-commercial or commercial sharing of underused goods and services, without permanent

ownership transfer, and through intermediary platforms. Though consensus is lacking, there are common elements to most definitions. These involve online intermediary platforms, directly connecting asset-owners with consumers; a peer-to-peer model (P2P), as opposed to traditional business-to-customer (B2C) models; and transactions focused on short-term access or rental, free of charge or for a fee (Rodrigues, 2019; Ganapadi and Reddick, 2018; Munkoe, 2017). Unlike traditional two-way B2C relationships, P2P models involve a three-way relationship between service providers, customers and an intermediary platform. Platforms typically do not own the assets which are shared among peers and largely act only as intermediaries in peer transactions (Katz, 2015). Codagnone and Martens (2016) developed a two-dimensional matrix which conceptually maps the SE. The vertical axis differentiates P2P and B2C models, while the horizontal axis distinguishes not-for-profit (non-commercial) and for-profit (commercial) sharing.

Figure 1: Two-dimensional matrix



Source: Codagnone and Martens (2016)

The SE is driven by P2P commercial sharing ventures such as Airbnb and Uber (Quadrant 2), recognised as defining SE examples. Quadrant 3 is effectively empty, as traditional B2C businesses are inherently profit-driven, though they may engage in non-profit ventures. In Quadrant 4, sharing activities are interconnected with B2C online activities, involving the majority of online

resellers and crowd-funding ventures. True sharing initiatives and niche commercial ventures generate little controversy. The paper focuses on Uber, which is found in the centre of most controversies. Presented insights are still relevant for the whole SE.

ADVANTAGES AND DISADVANTAGES

Since its emergence, the SE has been advocated for economic advantages and personal benefits it offers to participants. The arguments are that the SE optimizes underutilized resources, contributes to efficient resource allocation and productivity (Hossain, 2020; Kim, 2019; Benoit et al., 2017), reduces transaction costs and enables new markets (Ferretti, 2020; Schor, 2018), lowers costs of goods and services (Simic and Liem, 2023; Miguel et al., 2022; Kathan et al., 2016), increases market competition and pressures incumbents to adopt new technologies (Murillo, 2017; Woskowiak, 2014), promotes entrepreneurship, creates jobs, and contributes to economic growth and GDP (Hossain, 2020; Mauri et al., 2018; Harvey et al., 2017). The SE offers new income-generating opportunities and work flexibility. It enables individuals to prosper by renting their personal assets and effectively become micro-entrepreneurs (Dyal-Chand, 2015). Flexibility is another benefit. Providers can freely choose when and how much to work (McGinnis, 2018), which is important for those with part-time availability (Hira and Reilly, 2017). The SE could generate wider social benefits. It may enable effective access to expensive goods and services (Hossain, 2020), encourage resource efficiency and sustainable consumption, and have a positive environmental impact (Mi and Coffman, 2019; Piscicelli et al., 2018; Toni et al., 2018; Kathan et al., 2016). The SE could help reduce poverty and social inequality by widely spreading income opportunities for individuals with modest skills and limited options, while also making everyday life more affordable (McGinnis, 2018).

The SE also generates various concerns and externalities, primarily through regulatory disruption, affecting core stakeholders and third parties. Issues include employment disadvantages for providers, as well as reduced service quality, safety standards and customer protection, including platform transparency and data privacy issues (Mosaad et al., 2023; Ganapati and Reddick, 2018; Thorne and Quinn, 2017; Schor, 2016), promotion of unethical social behaviours and discriminatory practices (Frenken and Schor, 2019), disruption of established businesses, and other externalities affecting third parties and local communities (Hossain, 2020). SE presence can negatively affect commu-

nities through increased noise, traffic and pollution, and increased crime rates and non-civic conduct (Mosaad et al., 2023). Short-term renting negatively affects housing markets and housing affordability (Simic and Liem, 2023; Ganapati and Reddick, 2018). Critics have questioned SE's positive environmental impact, noting that its expansion may actually increase environmental costs (Schor and Vallas, 2021; Frenken, 2019; Murillo et al., 2017). There are also concerns about fairness, which are addressed in this paper.

FAIRNESS-BASED CONCERNS

Fairness issues are examined using a broadly Rawlsian understanding of fairness. The core Rawlsian concern taken on board is that the distribution of benefits and burdens from cooperative ventures should be fair and acceptable to all (Rawls, 1999). Fairness issues are examined across two dimensions: (1) on the micro-level, with regard to fair cooperation among SE ventures and fair market competition; and (2) on the macro-level of social justice.

The objection of unfair market competition arises when non-sharing businesses, subjected to higher levels of regulation, are forced to compete with sharing businesses that are not required to comply with the same requirements, which gives them an unfair advantage (Ganapati and Reddick, 2018). A similar issue emerges in competition between established and newcomer sharing companies, as most SE markets are dominated by few actors (Murillo et al., 2017). Both non-sharing and newcomers may thus struggle to compete on a level playing field. Another concern is that the SE may lead to the erosion of workers' rights and the corresponding race to the bottom. The SE involves employment disadvantages since providers are typically classified as independent contractors (self-employed), not as employees. Thus, workers do not have access to employee benefits, including minimum wage, unemployment benefits, training opportunities, career development or pension (Mosaad et al., 2023; Hossain, 2020; Eckhardt et al., 2019). For some, this may not be problematic since in the SE individuals transform their personal assets into productive assets, effectively becoming micro-entrepreneurs, managing their "businesses" according to their priorities and schedules. Thus, while regretful, these disadvantages may not be problematic since individuals choose their level of engagement, enjoying benefits of flexible work, which is something generally not available to employees. While that may be true for those with substantive asset-ownership, for others SE means insecure employment, earning uncertainty and unfavourable working conditions. SE workers are also more likely to accept unfavour-

able terms of cooperation due to their low bargaining power and lack of interest representation (Keller, 2020; Rahman, 2016). Labour unions and collective bargaining are often seen as safeguards of workers' rights. As independent contractors, however, workers may lack the right (or effective opportunity) to unionize (Levine-Schnur and Ofir, 2023; Quinn et al., 2021). Therein, due to the asymmetry of bargaining power favouring the platforms, workers cannot negotiate better terms of cooperation, and are placed in the "take it or leave it" position, especially if their options are limited.

The SE may also increase social inequality, rather than reducing it (Levine-Schnur and Ofir, 2023). Research suggests that the distribution of benefits disproportionately favours platform companies, property-owners, and those already well-off (Ferretti, 2020; Ganapati and Reddick, 2018; Davies et al., 2017). Inequalities may increase as individuals with substantive assets and flexible skills derive larger benefits from sharing activities (Ahsan, 2020; Frenken and Schor, 2019), while less advantaged individuals, lacking relevant assets and skills, may not meaningfully benefit. Platform companies gain significant advantages by exploiting inadequate regulations and avoiding taxation (Mosaad et al., 2023), denying governments (the public) their fair share in taxation, and limiting their capacity to reduce inequalities.

REGULATING THE SHARING ECONOMY

The SE has expanded within the context of, and was partially facilitated by, the relaxed - or non-existent - regulations (Ganapati and Reddick, 2018). Despite its advantages, the SE also generates significant externalities and fairness-based concerns, and has reached a size, in terms of market share and social impact, where additional regulatory action is required. Yet, many SE areas lack adequate regulation, creating significant uncertainty for the participants and third parties. The discussed concerns are not exclusive to the SE. Legal ambiguity surrounding the SE, however, may block traditional regulatory solutions. There is no consensus on what would be an appropriate regulatory approach for diverse SE arrangements. Policymakers are struggling to develop adequate guidelines, not helped by ongoing disputes, conflicting stakeholder interests, and platforms' ability to disrupt established rules (Drapalova and Wegrich, 2024).

REGULATORY CHALLENGES

The SE raises difficult legal questions. Are companies such as Uber or Airbnb only intermediary platforms in individual transactions, or something more? Are they really “new sharing economies” or merely “old businesses” utilizing new technologies? Are providers platform employees or independent contractors, and if the latter, should they be considered as private individuals or micro-entrepreneurs? Difficulty in providing clear answers to such questions creates legal confusion and increases uncertainty for the participants and third parties.

SE arrangements do not fully align with the established legal categories. The crucial issue concerns the contractual relationship among platforms and service providers, along with the corresponding liabilities and obligations. The issue is that the existing legal rules are designed for two-party relationships, while the SE involves three parties: providers, customers, and an intermediary platform. The three-party relationship complicates the liability distribution between platforms and providers, who are typically independent contractors, and often operate in casual capacity. For example, if Uber drivers cause an accident, who is liable for customer or third-party injuries – drivers, the platform, or both? In some countries, drivers, as private citizens, are not required to meet stricter taxi safety standards or have commercial insurance, while Uber may deny liability by claiming to only be an intermediary. As Katz notes (2015: 1999) there are issues with assigning higher liability to either providers or platforms. SE providers lack the “special relationship” with customers, which has traditionally been the ground for assigning higher obligations to providers. As passive intermediaries, platforms cannot be held indirectly liable for all accidents arising from platform transactions either. Most platforms, however, are not entirely passive, but exercise some control over providers and transactions, and have a financial stake in transactions. This suggests that platforms may (and indeed should) face more comprehensive obligations (Munkoe, 2017; Katz, 2015).

A related issue is whether SE providers should be classified as independent contractors or as platform employees. On the one hand, if platforms exercise some control, even indirectly through algorithm management, over the providers and set the terms of cooperation, that would suggest an employment relationship (or at least relevant employment-like relationship). If so, (intentional) misclassification of providers as independent contractors may simply be a strategy of platforms to minimize their liability, evade labour regulation, and transfer certain costs to providers, while significantly benefiting from

their work. On the other hand, platforms are not employers in the traditional sense since they are (typically) not asset-owners (providers are) and do not retain control over all aspects of peer transactions (Katz, 2015). Work flexibility and non-exclusivity are common to SE models, but not to traditional companies or standard employment relationship definitions. Treating providers as micro-entrepreneurs is also inadequate. Providers are often causal participants, operating on a smaller scale, and thus may not be able to comply with the same requirements as traditional providers (Katz, 2015). It would be unfair to only subject providers to higher regulatory burdens, and not include platforms, some of which are profitable multinational companies. Such a solution would enable platforms to unfairly benefit at the expense of providers, incumbents and third parties. The issue is not whether platforms are liable, rather to what degree. Determining whether platforms exercise sufficient control over providers, needed to establish indirect liability or employment relationship, requires case-by-case evaluation¹ (Katz, 2015). Whatever else may be true, platforms enable and facilitate sharing activities which otherwise may not even occur, or at least would not be as extensive. Platforms, as essential enablers and facilitators, cannot avoid responsibility for the consequences of sharing activities, from which they derive significant and disproportionately large economic benefits.

EU REGULATORY APPROACHES

Kirchner and Schüßler (2020) noted three approaches to how governments faced SE regulation. One involves avoiding obstructions to the SE markets, presupposing self-regulating mechanisms. The second effectively bans SE activities by reinforcing established rules. The third allows the SE markets to operate, but mitigates their unwanted aspects by adjusting SE activities within the existing regulatory frameworks, which are slightly modified. Governments combine these approaches, often favouring mitigating, and trim-and-adjust approach (ibid.). In Europe, some governments enforce stricter measures, while others are more welcoming. Uber is banned in Bulgaria and Hungary, or faces partial bans. Differences can be observed when comparing Germany (least accommodating), Sweden (more accommodating) and Estonia (most welcoming).

In Germany, Uber encountered problems from start and was soon banned due to court rulings enforcing the existing regulations. The issue was freelance

¹ One method is to use the so-called Uber test (European Court of Justice) (Rodrigues, 2019)

and unlicensed drivers (UberPop). Uber unsuccessfully challenged the ruling, withdrew from Germany, and later adjusted its practices to the existing regulation. The German approach reinforced the existing regulation, effectively banning Uber, in defence of traditional taxi providers (Thelen, 2018). Uber drivers are required to hold a special passenger transport licence [*P-Schein*], a taxi permit issued by the local authorities, pass a medical exam, and satisfy vehicle standards (Uber, 2024). Since 2019, Uber has partnered with taxi operators and car rentals, whose drivers already meet all the requirements (Thelen, 2018). Other Western European countries similarly impose stricter regulation.

In Sweden, Uber faced less challenges due to prior market deregulation in the 1990s. UberPop was banned, and the existing taxi regulation applied to Uber. The Swedish approach is more accommodating than the German due to efforts to adjust the regulatory framework so as to allow Uber operation [trim-and-adjust approach] (Thelen, 2018). The Swedish market was further deregulated due to Uber's presence. For example, in 2018 a new car-pooling category, exempted from taximeter requirements, was created. Taximeter was replaced, but drivers must be affiliated with a dispatch centre, which connects them to customers, registers the ride data, and organizes payments. Since 2020, Uber has been exempted from taximeter requirements (Oppegaard et al., 2019). All Nordic countries followed a similar pattern. Uber prompted changes to the existing regulations and deregulation. Licences are required for Uber drivers, but the criteria for taxi and professional licences are not demanding. Another aspect of deregulation was shifting regulatory authority from governments to platforms. Uber sets prices and has significant control over the working conditions (Sigurd, Oppegaard and Saari, 2020). The effort to deregulate markets, due to Uber's presence, distinguishes the Nordic and German approaches. Sweden and Finland are more accepting of Uber than Denmark, which has stricter rules. Uber left Denmark in 2017, due to the taximeter, video surveillance and other requirements (ibid.).

In Estonia, the home of Bolt (ex-Taxify), Uber's arrival initially generated public debates. Unlike countries where Uber faced bans, Estonia embraced it, creating favourable conditions for the SE. The culmination was the "ride-sharing law", which made Estonia the first European country to recognize ride-sharing as distinct from taxi businesses (Lanamaki and Tuvikene, 2021). Regular taxis are required to carry special insurance and use taximeters. The ride-sharing ones do not, and can use apps and regular insurance, but must be registered and provide receipts (ibid.). Uber drivers are only required to have drivers' licences, insurance, and service provider permits, which are easier to obtain than taxi licences. Estonia uses digital platforms for tax reporting.

Already lightly regulated, the taxi market was thus further deregulated (Kall et al., 2021).

Despite similarities, there is considerable regulatory diversity across the EU countries. Recent developments at the EU level have focused on regulatory harmonization, building upon the prior Digital Single Market Strategy and the Communication “European Agenda for the Collaborative Economy” (2016) (Dumančić, 2021). The adoption of the Digital Markets Act (DMA) and the Digital Services Act (DSA) has advanced the regulatory framework by clarifying platform liabilities. The DMA addresses market asymmetries aiming to prevent unfair competition by targeting large influential platforms. These “gatekeeper” platforms, defined by a strong economic and intermediation position, are subjected to the highest degrees of regulation (Regulation 2022/1925). Gatekeeping platforms include large corporations, i.e. Google, Meta, Microsoft, Amazon and Apple. Airbnb and Uber are considered as potential gatekeepers (Bostoen, 2023: 157). The DSA aims to prevent harmful and illegal activities, and ensure platform transparency and users’ safety and rights. The DSA assigns the highest obligations to very large online platforms (VLOPs)². Smaller companies have obligations proportionate to their size and ability (Regulation 2022/2065). Another recent development is the Platform Work Directive (PWD) (2024), which requires States to implement a presumption of employment (rather than self-employment) under certain criteria (i.e. platform control and direction) in accordance with national laws, collective agreements and EU case law. In order to refute it, platforms must offer evidence on the non-existence of employment relationships (Directive 2024/2831).

Despite recent developments, little real progress has been achieved, with crucial issues surrounding the SE remaining unresolved. Although the 2016 Communication initially created momentum, it was not legally binding and was followed by regulatory stagnation, facilitated by ongoing disagreements among the Member States. The DMA and DSA also do not directly address SE regulation. They are focused on large digital platforms, and not on platforms such as Uber and Airbnb, which are not yet considered as gatekeeping platforms and thus are not subject to the heightened regulatory requirements. The impact of the PWD may also be limited in practice given its deficiencies (Aloisi, Rainone and Countouris, 2023). The Member States are required to establish a presumption of employment, but the criteria for determining the employment status of SE workers are not harmonized at the EU level. This weakens its impact since States can define their own criteria, with a significant

² As of 2024, based on its own official report, Uber falls below this threshold

degree of discretion. States also have until 2026 to implement the Directive, raising concerns about its effective implementation, further delayed action and disagreement on its content. The EU regulatory approach to the SE thus remains uncoordinated, with ongoing disagreements effectively blocking regulatory harmonization and further substantive progress in the near future.

AN EFFECTIVE AND FAIR REGULATORY SCHEME?

The regulatory debate remains divided between those advocating self-regulation (or minimal interventions) and those demanding stricter regulation. Neither is adequate on its own. Robust government regulation may impede innovation due to information asymmetry favouring platforms. Though desirable in some areas, self-regulation is inadequate in areas such as labour rights or market competition. Platforms are unlikely to stop exploiting the inadequate regulatory *status quo* in the name of fairness without appropriate democratic oversight. Still, excessive government restrictions and/or *ad hoc* legal patches also appear inadequate.

Development of a principled regulatory approach involves two sets of dilemmas, focused on the perceived value of SE innovation. (1) If we find no value in SE innovation, there is no need to adjust the regulatory framework to better accommodate the SE. Established rules should be reinforced, even if that impedes SE development. If this is the preferred solution, there is little value in further debate. (2) If we find value in SE innovation, regulation that would transform SE ventures into traditional businesses should be avoided. Instead, we should develop a scheme that supports SE innovation while addressing its undesirable aspects. In contrast to demands for stricter regulation, this paper argues that SE regulation should not be restrictive or excessive. Rather, it should be flexible, leaving sufficient “breathing room” for effective self-regulation and further SE development, and ultimately, it should be fair.

Grounded in the ideal of fair distribution of cooperative benefits and burdens, an appropriate regulatory scheme should ensure fair cooperation among SE ventures and fair competition between sharing, non-sharing, and newcomer businesses. A fair scheme should also account for diverse stakeholder and public interests. This is essential for the scheme to be effective and reasonably acceptable to all. Developing a fair scheme requires a balance of conflicting stakeholder interests, which in turn requires some (maybe even substantive) compromises from all stakeholders. The next discussion provides a sketch of a fair regulatory scheme.

FAIR COMPETITION

Ensuring fair competition requires balancing conflicting stakeholder interests. Reducing regulatory and tax burdens for non-sharing businesses, combined with comparable duties for platform companies, is a good starting point. A uniform, one-size-fits-all, regulatory scheme may be inappropriate given the SE diversity. Uniform regulation, if excessive, raises fairness concerns since it may unfairly favour established, larger enterprises (sharing or non-sharing) over newcomers and smaller businesses. Larger enterprises are privileged as they can absorb or externalize regulatory costs, which is something newcomer and smaller businesses cannot do, and it reduces their likelihood of surviving on the market. These actors, and casual providers, may be subjected to undue burdens. It would be unfair for individuals occasionally renting a small room in their home to earn extra income to face the same regulatory burdens as larger providers. Uniform regulation, if restrictive, can impede experimentation, potentially denying a fair opportunity for newcomers to challenge incumbents through innovation.

An appropriate scheme should thus be based on tiered regulation. Beyond a basic level, regulatory requirements should be proportionate to the size and capacity of different ventures and providers, becoming increasingly stricter with their development and impact. Katz proposed that the degree of regulation should be linked to the volume of transactions. High-volume providers would face stricter regulatory and tax obligations. Less demanding requirements would be imposed on lower-volume providers (Katz, 2015). For example, given its market share, number of users, or transaction volume, Uber would face a level of regulation and requirements comparable to that of taxi companies of similar size. Compared to professional providers, casual providers would face more lenient obligations above basic requirements. Uber providers acting in capacity comparable to professional taxi drivers would be subject to similar requirements. The same principle would apply to newcomer and smaller Uber-like companies until reaching upper thresholds. Tiered regulation can provide a necessary degree of flexibility, it can be tailored to different sectors or SE ventures, and fine-tuned over time. Tiered regulation corresponds to the ideal of level playing field and fair distribution of regulatory burdens since it does not disadvantage smaller and occasional actors, nor arbitrarily privilege established and larger actors. It would also better balance the distribution of burdens among sharing and non-sharing companies with comparable size, market shares and transaction volume, enabling a level playing field without undermining SE innovation. Tiered regulation allows actors

to effectively (and legitimately) “choose” the level of regulation appropriate for them. The SE actors (platforms) would face a choice: remain on lower tiers, which offer lenience, but less profit; or expand as to increase profit, at the cost of flexibility. Tiered regulation aligns with the current EU framework, which considers platform size, and distinguishes casual and professional providers, when determining their liabilities.

Although attractive in principle, tiered regulation faces numerous practical challenges. One issue arises from its complexity, which can increase administrative and compliance costs, introduce uncertainty and make enforcement more difficult. Uniform rules are both easier to understand and to enforce. Regulatory thresholds may discourage ventures from developing beyond a certain size to avoid stricter regulation at upper thresholds. Another risk involves arbitrary cut-offs between thresholds, leading to regulatory discretion. The effectiveness of tiered regulation depends on the details and appropriateness of regulatory thresholds. Developing appropriate thresholds may not be adequately achieved at the theoretical level. Given various complexities, it may be preferable to approach this task through ongoing discussion and collaboration between the government and relevant stakeholders (co-regulation method).

FAIR COOPERATION

Ensuring fair cooperation requires balancing the distribution of cooperative benefits and burdens between platforms and providers. Tackling the (intentional) misclassification of SE workers and mitigating their employment disadvantages is essential. This issue cannot be adequately addressed through self-regulation due to underlying power asymmetry which enables platforms to dictate the terms of cooperation, even if indirectly, and thus unfairly benefit at the expense of workers and third parties. The issue is especially problematic when profitable platforms disproportionately benefit from workers’ contribution without ensuring adequate work conditions, compensation, insurance and effective bargaining opportunities.

Establishing an effective presumption of employment relationship and shifting the burden of proof onto platforms to prove otherwise is necessary, but not sufficient. Platforms may respond by modifying contractual terms for workers to avoid their reclassification as employees. Another issue are semi-professional providers falling short of employment criteria, while in practice acting in an employment-like capacity. Both concerns arise from a deeper issue of considering SE work only in terms of employment and self-employ-

ment. Such a simplistic dichotomy cannot adequately capture the existing (and potential) non-standard working relationships resembling employment relationships, and notably dependent self-employment. There is no consensus on a definition of dependent self-employment, but there are certain indicators suggesting it. These workers are economically dependent on the income from a single client, or a small number of clients, who exercise significant control over their working conditions and issue guidelines on how work is performed. They also lack decision-making powers regarding business operations (Williams and Lapeyre, 2017).

Two relevant insights, therefore, arise. First, platforms can easily misclassify workers as self-employed if the only other alternative is employment. Second, unless their status is recognized as sufficiently employment-like, dependent self-employed workers will remain inadequately protected and disadvantaged, although acting in a relevant employment-like capacity. Establishing a third legal category of dependent self-employed workers may be an effective solution for the issues of misclassification of non-standard workers and their ineffective access to adequate labour and social protection³. The following dilemma arises. The wider and more substantive a category of dependent self-employment is, the more limited the platform ability to misclassify workers would be. Consequently, a significantly larger number of SE workers would be covered by more extensive legal and social protection. This is desirable from the fairness-based perspective. However, the more substantive the notion of dependent self-employment, the more controversial it would be, making it less likely to generate sufficient political agreement necessary for its implementation and effectiveness.

The following issue is to ensure an appropriate level of social protection and benefits for different SE workers, including for various employee-like workers. One approach to this issue is to treat all SE workers equally and ensure broadly the same degree of social benefits. Denmark provides such an example. In 2018, an employment benefit system which treats all income sources equivalently was introduced so as to enhance access to unemployment insurance for non-standard and self-employed workers (OECD, 2019: 55). Being tied to the broader logic of the Danish flexicurity system, it may not be appropriate for various other EU countries, at least not without significant reforms of their social security systems. An alternative solution would be to

³ Some European countries have introduced such an intermediate labour category into their legal systems, i.e. Austria, Germany, Italy, Norway, Spain and the UK (PWC, 2022; OECD, 2019)

provide different degrees of social benefits, depending on the degree of workers involvement in the SE and their dependency. Social protections could also be made independent of employment status through portable worker benefits, which could be offered through security accounts for providers, into which platforms make regular payments (Ganapati and Reddick, 2018). Benefits are portable since they are tied to providers, regardless of the “employer” platform (Quinn et al., 2021; Rahman, 2016). The advantage of this proposal is that all SE workers would be included, removing the risk of unfairly disadvantaging some of them. It may thus be desirable to use such a system, in some capacity, so as to adequately insure all workers alongside other policies. From the fairness perspective, it matters less which specific approach is utilized, insofar all SE workers are appropriately protected and have effective access to adequate social benefits.

Alongside ensuring adequate labour and social protection, all SE workers, including those self-employed, should be ensured an effective opportunity to select their representative and engage in collective bargaining with platforms. This provision would enhance the workers’ bargaining power, and contribute to a fairer distribution of cooperative benefits. In addition to being controversial, a practical issue here is to actually organize diverse SE workers, and effectively enhance their bargaining position given the decentralized nature of the SE.

CO-REGULATION

One might object that, while not being ground-breaking or even sufficiently feasible, the discussed proposals unfairly burden platform companies and subtly aim to transform the SE into more traditional business models, underestimating its innovativeness. The final point is that regulation should be developed in collaboration and mutual agreements with platforms and core stakeholders, including local communities and social actors. Since neither self-regulation nor government regulation alone are adequate, Finck (2018) proposes co-regulation as a third option, as being suitable for the EU. In a co-regulatory model, the legal authority (EU) would set objectives to be achieved by entrusted parties (platforms, social partners), while allowing local authorities to adjust responses to a specific context. Co-regulation presupposes that binding rules emerge through consultations and interactions among various actors (platforms, workers, customers and incumbents’ representatives) (ibid.). The advantages of co-regulation are twofold. Co-regulation enables flexibility and beneficial self-regulation under democratic oversight, while collabora-

tion between involved stakeholders contributes to the development of effective regulatory mechanisms reasonably acceptable to all involved parties, which reduces compliance costs and increases regulatory effectiveness through platform regulatory autonomy and social pressure. Thus, given the ongoing disputes and regulatory stagnation, co-regulation presents itself as a pragmatic approach to discovering appropriate regulatory mechanisms through mutual collaboration and agreements consistent with the principle of subsidiarity. Notable examples of co-regulative schemes are partnership agreements between Airbnb and the city of Amsterdam, and the city of Milan. Although unrelated to the SE, another example comes from the Nordic countries in which workers' salaries, working hours and other benefits are discussed through negotiations among labour unions, employer organizations and local governments, resulting in industry-wide agreements. Co-regulation has the potential to resolve various regulatory issues without having to reach a prior substantive consensus, either on the national or the EU level, on what would be an appropriate overarching approach to SE regulation. Rather, effective regulatory mechanisms are discovered and implemented through collaboration. Platforms are likely to engage in co-regulatory agreements if the alternative is stricter regulation which restricts their autonomy and, more importantly, limits the scope for the further evolution of self-regulatory mechanisms. While co-regulation is certainly promising as a pragmatic solution, making it effective in practice remains a challenge, especially if trust and willingness to cooperate are absent. While co-regulatory mechanisms can function without a wider consensus on the appropriate approach to SE regulation, their effectiveness presupposes an agreement on some basic principles, which would guide the co-regulatory process and enable reaching fair mutual agreements.

CONCLUSION

The SE is a disruptive force that challenges the *status quo* in many countries, and whether it will be a positive or a negative disruption remains unclear. The reality is that the SE has become a global phenomenon, unlikely to disappear anytime soon. There are some large shadows lingering over the SE, especially those related to fairness concerns. Despite the ongoing concerns, the SE has a significant potential to create meaningful long-term benefits for its participants and societies. Its development stands at a crossroad. Appropriate regulation could be the deciding factor in determining the future SE evolution. Regulating the SE is a challenging task, not facilitated by ongoing disputes

and conflicting interests. The central point of this paper can be surmised as follows: if we find value in SE innovation, regulations that would transform SE ventures into traditional businesses should be avoided. The focus should be on developing a scheme that supports SE innovation while adequately addressing its undesirable aspects in a fair manner, reasonably acceptable to all. What does the future hold for the European sharing economy? As it seems, ongoing disputes, lack of regulatory harmonization and further stagnation, while the problems presented by the SE will continue to accumulate and likely become even more concerning. Uber and Airbnb already present enormous regulatory challenges, and are followed by the development of even more complex and decentralized blockchain-based platforms, which present further unique challenges. Many issues remain open, some of which were only partially addressed, especially those related to practical challenges and feasibility of the sketched scheme. Our conclusions thus remain limited, and require further discussion. Co-regulation and closer cooperation with platforms may be crucial in discovering new and effective regulatory mechanisms by providing a necessary degree of flexibility needed for the evolution of self-regulatory mechanisms. Further decentralization and democratization of regulation may be critical to keep up with the emerging digital cooperative models. Its effectiveness depends on the willingness of involved parties to collaborate and reach agreements, which presupposes sufficient agreement on some basic principles. The ideal of a fair distribution of cooperative benefits and burdens can carry most of the normative burden and generate agreement on the corresponding principles of cooperative fairness, tier-based regulation and co-regulation. Efforts have to be invested into actually building such an agreement in light of the ongoing disputes across EU countries. Building up such an agreement, grounded in the ideal of fairness, which would then guide further discussion and collaboration, may indeed prove to be more important than trying to reach a substantive agreement on the specific details of an ideal regulatory approach to the SE. If such an agreement can be achieved, then even more radical proposals, such as organizing SE ventures in accordance with the ideal of workplace democracy, may not be unfeasible. Whether such an agreement can be effective without transferring additional decision-making powers to the EU level, especially in the areas of fiscal or social policy, remains uncertain.

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OTHER TOPICS

A REVIEW OF THE MAIN HISTORICAL FACTS ON THE DOUBLE-ENTRY METHOD AND THE ACCOUNTING VALUATION, AND THEIR CONTEMPORARY PURPOSE IN FINANCIAL ACCOUNTING

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Today's financial accounting is subject to numerous tests and trials in which the modern economy functions. It reflects what is happening not only in the economic world, but also in the socio-political. The purpose of this article is to focus on some key historical moments in the development of the two accounting methods – double entry and valuation, as they are the basis for the development of other accounting methods. The limited scope of the article does not allow us to conduct a more thorough study, and for this reason, emphasis will be placed on the importance of these two basic accounting methods in the conditions of modern digital financial reporting.

The methodology applied in this article is a systematic approach based on the recommendations of PRISMA, with consistency and coherence of the presentation, aimed at drawing basic conclusions. In the first part of the presentation, a scientific review and analysis of historical facts with regard to establishing the two accounting methods is conducted. A historical retrospective of historical data has been made, which is aimed at remembering the historical roots and personalities from which the overall development of accounting began. The second part of the article presents contemporary data derived from studies on the progress of financial accounting, which stem from the modern way of applying valuation as an ac-

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counting method and double entry. The studies are derived from reference databases such as EBSCO, SCOPUS, WoS, and others, which is evidence of research validity.

The results show that these two methods are the most frequently studied and discussed methods in the accounting circles when it comes to the way of presenting a given accounting object in financial statements in a digital environment. This study contributes to the additional body of knowledge by providing empirical evidence on the benefits of these two main methods of accounting. For the first time, a direct emphasis is placed on these two methods in terms of their meaning, and they are not studied only as a means by which a given accounting object is changed within an accounting vision.

Keywords: *Accounting method, valuation, double entry, accounting, financial reporting*

JEL classification: *M41, M42, M48, M21*

INTRODUCTION

Accounting, as a science and practice, has its deep historical roots. This is perhaps one of the most ancient sciences, along with mathematics, which has developed consistently until taking the form we know today. Many modern financial reporting researchers emphasize the current regulatory changes and the resulting transformations that occur in financial reporting, and do not place as much focus on the changes in accounting methods and subjects. The scope of a very large part of modern research is to clarify the issues of how to present information in the financial statement, how to present the explanatory notes to the financial statement, what the tax effects are on the change in the relevant accounting and financial object, etc. However, let us take stock that this is NOT the goal of accounting science – this is accounting practice, which changes under the influence of regulatory changes to cover specific requirements, and sometimes even these changes are due to the lobbying of specific large enterprises.

The purpose of this article is to present the importance of the two main accounting methods – the double-entry method and the valuation method, for modern financial accounting, by achieving the following tasks:

1. Making a retrospective presentation of the two methods from a historical perspective, going back into the historical past.

2. Revealing the changes in the importance of the double-entry and valuation methods over the years.

The study poses the following hypotheses for testing:

H1: The retrospective approach reveals not only the historical events that relate to accounting, but also presents the changes in accounting methods over the years.

H2: The double-entry method has developed in parallel with the valuation method.

In order to prove the hypotheses, the research encompassed the period from 1990 to 2024, during which focus was placed on the presented facts regarding the historical development of accounting.

The structure of the presentation is consistent with and aimed at meeting the scientific requirements, namely the following:

1. The theoretical aspects regarding the most important historical moments in the development of accounting are consistently presented.
2. A literature review is made of some of the more significant contemporary literary sources and of the researchers who have studied issues related to the development of accounting from a historical perspective, who have analyzed the two methods of double-entry bookkeeping and accounting valuation.
3. The methodology of the development is presented as a sequence of actions in order to prove the hypotheses.
4. The results of the study are grouped and summarized. They are visualized using a table and figures.
5. Discussion questions, conclusions and inferences are stated separately.

THEORETICAL BACKGROUND

Nowadays, it can be boldly stated that scientists are unanimous (Svrakov, (Svrakov, 2014); Pyatov, M. L. (Pyatov, M. L., 2013); Pyatov, M. L. (Pyatov, M. L., 2017); Solovey, T. N. (Solovey, T. N., 2017); Pyatov, M. L. (Pyatov, M. L., 2024); Genov, G., Todorov, G., Radev, G., Georgiev, V., Filipova, F. (Genov, G., Todorov, G., Radev, G., Georgiev, V., Filipova, F., 1997); Bogdanov, X (Bogdanov, X, 2001); Anes, R. D. (Anes, R. D., 2002); Donoso Anes, R. (Donoso Anes, R., 1994) etc.) that the basis of modern financial accounting is the method of double entry. Historical records indicate that the method was first described by Benedetto Cotrugli in Naples in 1458, in his book *Della mercatura et del mercante perfetto* (“On Trade and on the Perfect Merchant”), but his book was

officially published 113 years later, i.e. in 1573 by Frane Petrić in his publishing house *All'Elefanta* in Venice (Skuhala Karasman, I., 2022). Scholars have discovered that when the book was first published, the publisher Frane Petrić made changes to the way Benedetto Cotrugli described the method in his original book. The question is why the publisher intervened and made changes to chapter 13 of Cotrugli's original book. According to Željko Muljačić, this was due to the following reasons (Muljačić, 1995):

- * the publisher wanted to modernize the method to be in line with the modern commercial conditions, i.e. to hide the archaic nature of the method;
- * merchants at that time already had much more modern manuals for keeping commercial books.

Therefore, the first officially available book describing the double-entry bookkeeping method was Luca Pacioli's book published in 1494 – “All About Arithmetic, Geometry, Proportions and Proportionality” (*Summa de arithmetica, geometria, proportioni et proportionalita*). For a long time, it was assumed in scientific circles that this was “Pacioli's method since he was its discoverer”. However, this statement is very wrong and extremely inaccurate. The main purpose of his book was to serve as a guide for all existing mathematical knowledge, in which the method of double entry accounting was more precisely presented as an example of this type of mathematical knowledge (Hernández-Esteve, 1994).

Another historical fact about the double-entry method is that even before the publication of Luca Pacioli's book, this method was taught in abacus schools in Italy as a mathematical method. With the help of the double-entry method, many practical examples were presented, through which mathematical regularities and rules were explained. However, Luca Pacioli's contribution will remain since he most accurately described this method and presented it in his book, and it is no coincidence that after the publication of his book, the method was called the “Venetian method” or “Venetian technique” (Mari LM, Picciaia F., 2018).

According to M.L. Pyatov, “Accountants always work in certain historical conditions, in which a certain form of economic relations, socio-political conditions, legal norms, economic relations appear, change, and the technological process follows its path” (Pyatov, 2024). Therefore, nothing is permanent in accounting practice, and everything is subject to change as a response to the new conditions of the environment.

Another method has influenced modern financial reporting, namely the accounting valuation. We must admit that there is no way for an accounting

object to be presented in modern digital conditions without the presence of the corresponding assessment form. Historically, with the development of accounting, the question of the valuation of accounting objects and the application of reporting measures has been raised. The interesting thing about this method is that the method of its application depends on the judgment of the enterprise, the judgment of the chief accountant or accountants, i.e. what is most important here is the human factor, and not so much artificial intelligence. It is a valuation that is performed by a given individual, and artificial intelligence expects to be asked this valuation. Many researchers assume that we still have accounting regulations that are very strict in terms of accounting reporting and the presentation of information in financial statements (Filipova, 2008). This is, in fact, true, but to a certain extent! The choice and manner of applying accounting methods and accounting practices remains a choice made by the enterprise. The purpose of IAS/IFRS is, more precisely, to provide guidance (Pounder 2009), since “International Financial Reporting Standards are an accounting framework based on principles rather than rules, which means that the standards allow companies some freedom in their accounting practices” (Nandakumar et al., 2010). According to Mert, I. (Mert, I. 2022) the existence of multiple accounting practices, accounting requirements, and the availability of freedom to make accounting decisions, creates many potential problems, one of which is the difficulty in valuation. This problem is created not only by the multitude of accounting standards, but also by the conceptual difficulty in determining the correspondence between the standards and more specific criteria for information quality and other requirements in accounting (Needles and Powers, 2010).

Other methods of accounting, which are documentation, inventory, accounting accounts, balance sheet summary, and summary of accounting data, have developed in parallel with the methods of double entry and valuation. The limitations of the paper do not allow us to reveal more historical facts related to the development of accounting, but it can be assumed that each method of accounting has its weight and importance in the performance of accounting, and if there is any accounting error, omission, or abuse, it is due to the incorrect application of a given accounting method.

From a historical perspective, the Securities and Exchange Commission (SEC), which was established after the Great Depression of 1929, has made a great contribution to the development of accounting. The contributions of the American Accounting Association (AAA), the American Institute of Certified Public Accountants (AICPA), and the Institute of Management Accountants (IMA) should not be underestimated, as they have also historically left a lasting mark on the development of accounting.

Flipping through the pages of scientific research devoted to the history of accounting, we find that there are scholars who have made a connection between economic theories and accounting. For example, according to Mert, I. (Mert, I. 2022), “it is appropriate to examine Smith’s theory of value to establish how value becomes a more complex and integral component of accounting theory. The discussion of value applied to accounting is inevitably complex since accounting has value in itself and is also a means of recording the value of goods and services”.

Based on everything stated so far, it can be assumed that the development of accounting, i.e. its complete form that we have today, which is applied digitally with the help of various software products, has historically evolved together with all other sciences and economic theories. This relationship is explainable through the fact that accounting presents all the dependencies and regularities that occur in the surrounding economic world and are relevant to the development of an organization.

METHODOLOGY

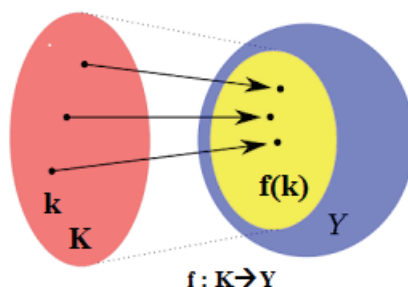
Due to the limited scope of the article, a literature review is used as the main method in this study. The literature review covers studies focused on the history of accounting, taking into account the publications that are presented in the leading bibliographic and abstract databases such as SCOPUS, WoS, EBSCOhost, RePEc, etc. A systematic approach based on the recommendations of PRISMA (A. Liberati, J. Tetzlaff, D. G. Altman, 2009; Nedyalkova, 2024) was applied. The specified methodology has been tested and applied by other scientists, such as Lambovska M.R., Raitskaya L.K. (Lambovska M.R., Raitskaya L.K., 2022), Lambovska M.R. (Lambovska, 2018d), and for this reason we rely on it as a proven method of scientific research.

The sequence of methodology in this scientific study is as follows:

1. Determining the scope of the study and the problems that will be the subject of the study.
2. Determining the reliability and validity of the data we have. The reliability of the information is guaranteed by the extraction of primary data from the leading bibliographic and abstract databases such as SCOPUS, WoS, EBSCOhost, RePEc, etc.
3. The strategy for electronic search in the databases is by key phrases:
 - In the SCOPUS database, K1 (*accounting* OR # history* OR #*method*).

- In the WoS database, K2 (*accounting* OR # *history* OR # *method*).
 - In the RePEc database, K3 (*accounting* OR # *history* OR # *method*).
 - In the EBSCOhost database, K4 (*accounting* OR # *history* OR # *method*).
4. Comparison of the displayed data (Fig.1)

Fig. 1: Comparison of the output data



Source: Own editing

Comparison is important for the study and is an important stage of the methodology. With the help of comparison, it is possible to find the arguments for other quantities. In mathematics, comparison is carried out by the function $y = f(x)$, while in our case the comparison will be in the form $y = f(k)$. Graphically, this comparison can be represented using Fig. 1,

where:

Y – is a function of the argument **k**.

5. Deriving the final results of comparing the data and drawing conclusions.
6. Comparing the data against the established criteria.

RESULTS

In the study of double entry and valuation as elements of the accounting method, we conducted a very thorough study of the literary sources. What we noticed is that in late 2024, the priority in research was given to the issues of

accounting digital transformation, but in the older sources another direction in the studies was observed, namely referring to the essence and application of the accounting method and its historical development. The period for which we examined the scientific research is from 1990 to 2024. The scope of the article, as a scientific study, does not allow us to make a more in-depth scientific analysis over time. Here, we indicate only 10 literary reviews since it is impossible to present all the scientific publications we have reviewed. We present these 10 literary reviews with their scientific weight and comprehensiveness, due to their scientific innovation in the research, but this does not mean that the other sources did not make scientific contributions. For better clarity, we illustrate the collected information by presenting it in Table 1. The literary sources presented in this part are those most visible in the Scopus and WoS databases, as well as sources that are in the top positions of the indicated databases, i.e. these are significant publications proposed by the first keyword of the relevant databases.

Table 1: Literature review of scientific studies in the SCOPUS database that focus on the historical development of financial reporting

№	Author	Title of the article or book	Aim of the study	Results of the study
1.	Castaldo, F., Porretta, P. and Zanda, S. (2024)	Recovering the Dormant Values of Accounting to Navigate the Challenges of the 2030 Agenda and Beyond	This paper presents a critical review of the current state of the accounting discipline and raises the question of its future trajectory. The study aims to show that the path to follow is the one followed by the masters of the discipline, which is at the beginning of the rediscovery of social and moral values and shared values.	There is no need for a new accounting science with new paradigms, but only for the restoration of the social and moral values of accounting that have lain dormant throughout the dusty centuries of human history.

№	Author	Title of the article or book	Aim of the study	Results of the study
2.	Svitlana Semenova, Olga Shpyrko, Olena Androsenko, Olena Kolumbet, Iryna Vorchakova (2024)	The Essence of Goodwill in Disclosing the Intangible Value of Business in the Context of Digital Transformation	The study of the history of development of the concept of reputation allowed us to identify the main stages of its formation as an object of accounting, reporting, and management.	It is proposed to define reputation as the intangible value of a business, reflecting its reputation, brand, customer loyalty, intellectual property, innovative and technological capabilities, digital user experience, online presence, and a set of other unique intangible assets that together contribute to the sustainable growth of the company's market value and the creation of competitive advantages, allowing adaptation to changes in the era of digital transformation.
3.	Hoffmann, S. & Zeff, S. A. (2024)	“American Bookkeeping” in the Late 19th and Early 20th Centuries Which Was Not American	This article conducts a study of the circumstances surrounding an ‘invention’ by Edmond Degrange père in 1804 which was said to be ‘American’. Degrange sought to simplify double-entry bookkeeping by combining the journal and ledger on a single page.	The main conclusion of this study is that many in Europe at the time believed that this accounting method had much in common with concepts attributed to America, such as ingenuity, pragmatism, and efficiency. This insight cautions against concluding the historical origins of accounting concepts simply by referring to names, labels, and denominations. The researchers also find that they can be interpreted as a further indicator of the inter-denationalization of accounting practice and thought in the late 19th and early 20th centuries because they demonstrate how a common label “American” – perhaps also as a synonym for non-European – was used in different European countries for the same accounting method.

№	Author	Title of the article or book	Aim of the study	Results of the study
4.	Alharasis, E. E., Haddad, H., Al-Shattarat, H. K. & Al-Ramahi, N. M. (2024)	Summary on the Development of Accounting and Auditing Practices towards IFRS-IAS/ISA in Jordan: Historical and Theoretical Perspective	This article examines the evolution of accounting in the Middle East region, with a focus on Jordan. The article examines the history of accounting and auditing in Jordan and how it has developed in relation to International Accounting and Auditing Standards.	There are several ways in which this paper adds value to knowledge. First, this solid work is based on the economic, political and regulatory landscape of Jordan. Second, the study uses factual data to identify the key elements that enable significant improvements in accounting processes in the region. Third, to address the vacuum in our knowledge about the evolution of accounting systems, especially in Jordan, this study outlines the key implications that followed this implementation at the local level. Fourth, by using the institutional theoretical perspective, it bridges the gap between the adoption of IFRS and the inclusion of institutional aspects.
5.	Kim, O. (2013)	Russian Accounting System: Value Relevance of Reported Information and the IFRS Adoption Perspective	The article examines the meaning of value.	The results indicate that information produced by IFRS-reporting firms is more value relevant, which suggests that adoption of IFRS is likely to result in improved information quality.
6.	Holthausen, R. W. (1990)	Accounting Method Choice: Opportunistic Behavior, Efficient Contracting, and Information Perspectives	This article views the choice of accounting method as a means of improving the monitoring capabilities of contracts that rely on accounting numbers.	As a result, the article presents how accounting method choice affects the monitoring characteristics of contracts and distinguishes between hypotheses based on the three perspectives on accounting method choice.

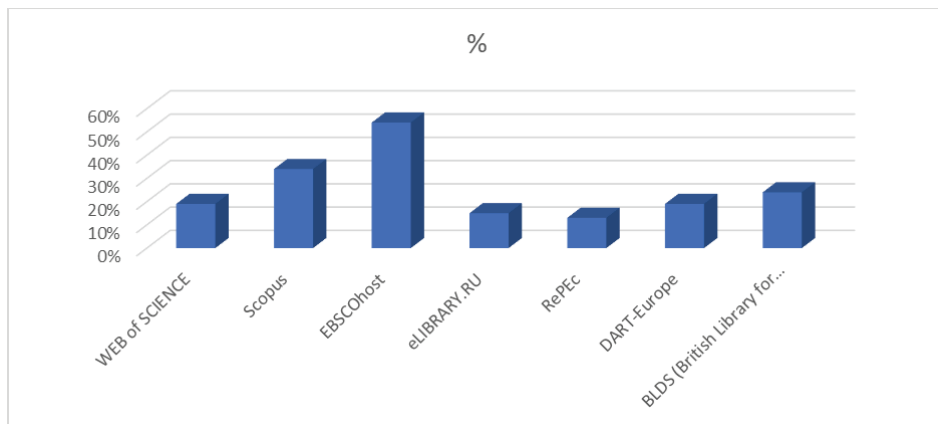
№	Author	Title of the article or book	Aim of the study	Results of the study
7.	Toshmamatov, N. (2018)	Some Theoretical Aspects of the Accounting Method	This article examines and analyzes the theoretical aspects, content and essence of the elements of the accounting method.	In specialized educational and scientific literature, when substantiating double entry, it is necessary to proceed from the following: registration of changes occurring in goods and money is carried out under the action of two mathematical expressions, in the form of an increase and a decrease for each object separately; what is the material basis for recording the business transactions performed on the debit of one account and on the credit of the second account; what objective necessity is caused by; recording in equal amounts of the business transactions performed on the accounts of accounting.
8.	Spear, N. A. & Leis, M. (1997)	Artificial Neural Networks and the Accounting Method Choice in the Oil and Gas Industry.	In this paper, the authors develop three supervised artificial neural networks (general regression, backpropagation, and probabilistic) to predict the accounting method choice by oil and gas producing companies.	The results of this study prove that general regression neural networks are very suited to this type of application and they outperform traditional statistical techniques. The authors confirm these results using two out-of-sample data sets from two different sample periods and after conducting numerous simulations with different network topologies. The authors believe that the success of this network is induced by its ability (1) to model accounting method choice as continuous valued outputs rather than categories, and (2) to build on the non-linearities and interactions among the posited variables.

№	Author	Title of the article or book	Aim of the study	Results of the study
9.	Chase, B. W. & Coffman, E. N. (1994)	Choice of Accounting Method by Not-for-profit Institutions Accounting for Investments by Colleges and Universities	This study reports a preliminary empirical investigation into the relation between the choice of investment accounting method used by colleges and universities and factors such as type of institution, endowment size and returns, and debt.	The results indicate that the selection of investment accounting method is influenced by type of institution, endowment size and returns, but not by debt covenants.
10.	Craycraft, C., Sedo, S. & Gotlob, D. (1998)	Foreign Operations and the Choice of Inventory Accounting Methods	The purpose of this paper is to determine if a firm's level of foreign operations influences its choice of inventory cost flow assumptions for its U.S. inventory.	The results indicate that firms with higher relative levels of foreign operations are more likely to use a non-LIFO inventory method for their domestic inventory than firms that are less involved in foreign markets.

It can be seen in Table 1 that the literary sources present a good historical experience of various scientists regarding the application of the accounting method from different aspects in practice. It is evident that in recent years there has been a variety of accounting problems studied by the scientists, and these problems are studied precisely from the position of applying the accounting methods. Many new events, facts and objects are explained in accounting practice, but at the same time, in these literary sources, the adaptation and modification of the accounting method elements in view of these changes is observed.

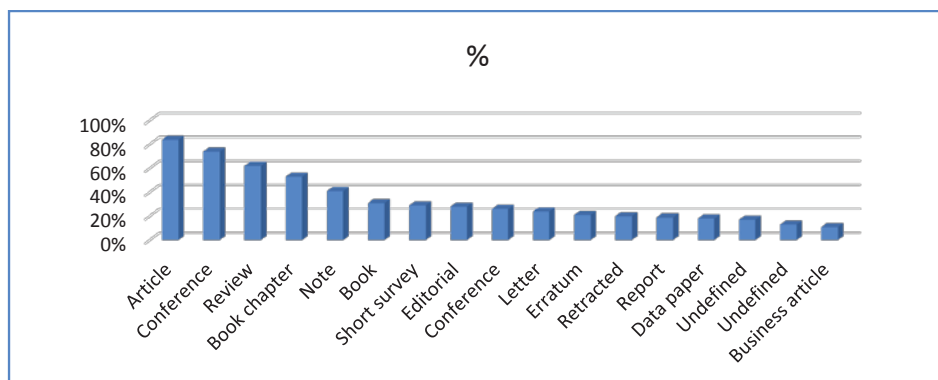
We also examined the European databases in our search for published official studies in the field of accounting history. The study conducted for the period from 1990 to the end of 2024 found that most publications are in the bibliographic and abstract databases of EBSCO, followed by SCOPUS and WoS. The studied data are presented in Fig. 2.

Fig. 2: Representation of the proportion of publications focused on the history of accounting in the largest bibliographic and reference databases



Source: Own editing

Fig. 3: Ranking of published studies in the field of accounting history, presented in the form of various scientific publications



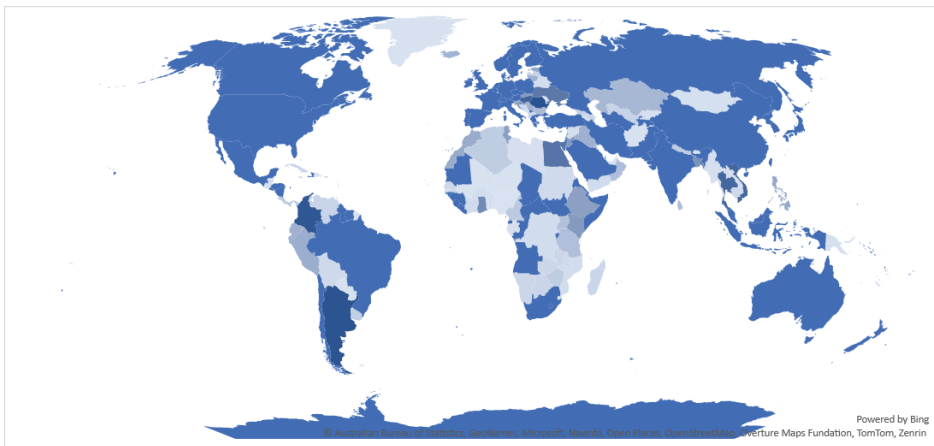
Source: Own editing

From the data presented in Fig. 3 it is evident that most studies in the field of accounting history have been done in the form of articles (98%), followed by conference reports (87%), scientific reviews (70%), and lastly, publications in the form of data papers (17%). This trend in the preferred form of publications can be explained by the following facts:

1. Journals are much more easily accessible and distributed compared to other scientific publication forms.
2. Writing an article and report takes much less scientific time compared to a book or a book chapter.
3. Participation in conferences is not always tied to the mandatory publication of a scientific paper. Many of the conferences are open access and the participant can attend as a listener or as a debater, but does not necessarily need to present a report.
4. Data papers are specific publications containing data and are peer-reviewed. Not all journals allow for the publication of data papers, as they must also provide reviewers for the relevant databases used in the article.

Using the databases from literary sources, we were also able to derive information about the major countries regarding their attitudes towards research and study in the field of accounting. We visualize the research in Fig. 4, as follows:

Fig. 4: Map of the countries that have conducted the most significant research in the field of accounting history



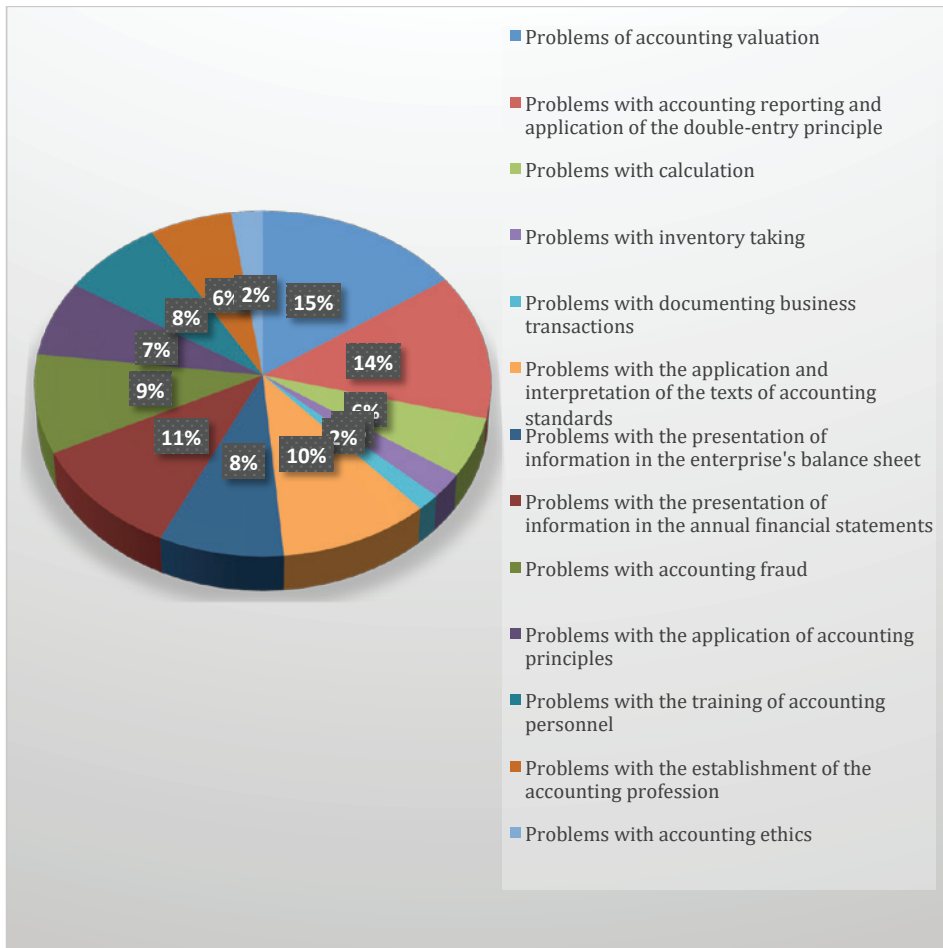
Source: Own editing

The study found that the most research in the field of accounting history was conducted in the USA, Great Britain, China, Canada, Germany, etc. (Fig. 4). This can be explained by the fact that these countries are the leading economic countries in the world and are the generators of digital industrial changes. Each economic change reflects on the accounting activity, at least through the identification and emergence of a new reporting object for which

a new accounting interpretation is required, and finding the correct accounting valuation through which it can be presented in the elements of the annual financial statements.

From all the information available in the main databases of Scopus and WoS on the history of accounting, we noticed that in every article that explores the historical development of accounting, other accounting issues are also touched upon along with this issue. The collected information is visualized in Fig. 5, as follows:

Fig. 5: Graph of the accounting issues most frequently researched from 1990 to 2024



Source: Own editing

From the comprehensive research we conducted, it is evident that, together with the study of the history of accounting, various accounting problems regarding the application of accounting activities in practice have been studied over the years. Fig. 5 shows that the most studied issues are those related to the problems of accounting valuation and its application. They account for 95% of the studies, explaining at what valuation the accounting object should be presented and how it should be evaluated. A total of 87% emphasize the problems of double entry, while 68% of the studies focus their attention on the problems of presenting information in the annual financial statements. Interestingly, there are many studies on the content and structure of the accounting balance sheet, i.e. 54% of the studies are aimed at studying the problems of presenting information in the enterprise's balance sheet. It is also interesting that 59% of the studies are aimed at the problems of accounting fraud in practice. In our opinion, this is a significant percentage of research and every economist should think and reflect when faced with some summarized information, examining whether it is correctly presented or contains misleading information. A total of 45% of the research is aimed at studying the application of accounting principles, and 48% examines the problems related to the training of accounting personnel. The problems with the training of accounting personnel represent a significant problem, which is evidently studied together with the historical development of accounting. The ability to deal with information, figures and data, and their accurate presentation through the most correct application of accounting principles, were issues that were studied in parallel in the accounting scientific circles. Problems related to conducting an inventory, problems with calculation as an accounting technology, and problems with ethics in accounting have been studied to a lesser extent.

Taking into account all the information presented, as well as the visualization put forward in Fig. 5, it can be assumed that the two working hypotheses stated at the beginning of the paper are proven. It can be assumed that all this is evidence of the first hypothesis, i.e. that with the help of the entire retrospective approach, looking back in time, we understand not only the historical events that influenced the development of accounting, but we can also see that the accounting problems that existed for the relevant historical period are revealed, and we understand how the overall accounting method has changed.

Furthermore, the data presented in Fig. 5 show that all the problems that have been studied relate to the application of the overall accounting method regarding its principle and consistency. In order to implement double-entry accounting, we must have a good base built on the knowledge and skills of accountants, while the correct valuation of a given accounting object and its

presentation in the financial statements also depend on and are determined by the competencies of accountants. Therefore, it can be assumed that, in accounting, everything is interconnected and is the result of a correct judgment of the accountant himself.

Based on everything stated so far, it can be assumed that the history of accounting has always been the subject of research by various scholars. In recent years, many historical events and facts from the history of accounting have been revealed that were not known until now. Despite these discoveries, which nevertheless fill in the historical gaps in the history of accounting, it can be assumed that the basis of all transformations in accounting is the observance of the double-entry method and the application of the valuation method. These two methods are the basis for adapting financial reporting to the new modern digital conditions in which all business units are developing.

The change in the economic conditions in which accounting develops determines all the current problems that accountants systematically face and must systematically solve. Accordingly, this results in many new horizons for the development of accounting, changes in methodology, and changes in the technology of reporting. According to a study by Robalo, R. & Costa (2017), accounting is changing with such rapid dynamics that even today one often hears accountants exclaim and say “It wasn’t like this before”, “We worked a lot, but things were different then”, “Today they demand a lot and want everything to be done yesterday”. Everything that accountants do today remains their professional handwriting and imprint. The practitioners themselves also write the modern history of accounting, and we scientists are the ones who summarize the data and facts. Who is the greater accounting historian, the practitioners or the scientists? Both personalities can be accepted. Going back in time, both Luca Pacioli and Benedetto Cotrugli, and many others, were practitioners above all. They described the situation for that time and for that period. Of course, history shows that innovation was allowed over the years, such as the proposal of the Russian practitioner Fedor Venediktovich Ezer-sky (1836-1915) aiming to establish the triple Russian accounting form, which subsequently failed to be established, similar to some other accounting forms (E.G. Waldenberg, 1891).

Nowadays, since there is a great dynamic in changes to regulatory acts, accountants strive to cover numerous tax requirements, international requirements for the presentation of information in financial statements, integrated reports, presentation of additional information, and valuation aimed at the sustainability of enterprises. Some scientists working in the field of exact sciences (mathematics, physics, chemistry, etc.) would say that this calls into question

accounting as a science, however accounting practitioners today would confirm that accounting is not an exact science, but rather a practical activity.

Based on everything stated so far, we can assume that the first hypothesis H1 is proven. With the retrospective approach that we applied for the period from 1990 to 2024, it has been established that history reveals not only historical documents and facts, but also presents the changes in the accounting method. A large part of the scientific research for the period from 1990 to 2024 also proves the second hypothesis H2, namely that the double-entry method has developed in parallel with the valuation method.

Based on everything presented above, it can be assumed that the history of accounting has always been the subject of research by various scholars. In recent years, many historical events and facts from the history of accounting have been revealed that were not known until now. Despite these discoveries, which nevertheless fill in the historical gaps in the history of accounting, it can be assumed that the basis of all transformations in accounting is the observance of the double-entry method and the application of the valuation method. These two methods are the basis for adapting financial reporting to the new modern digital conditions in which all business units are developing.

DISCUSSION, CONCLUSION

There are many discussions in the field of accounting history, not only from the point of view of the stages of development of accounting theory and the application of accounting methods, but there is also a trend in scientific research aimed at searching for historical figures and individuals who laid the roots of financial reporting in the respective countries and regions (Generalova, N. V., Pyatov, M. L. & Sokolov, B. I., 2024). The discussion among scientists in the recent years has become even more fierce and controversial, as many scientists believe that it is necessary to distinguish between practical accounting methods and methods that are aimed at the scientific study of accounting. Others are also working in this direction, such as Khanna, B. (2008), Smith (2003), Nedyalkova (2023), Nedyalkova (2019), etc. This means that financial reporting and accounting in particular can be studied and analyzed from different points of view, from different perspectives, and the issues related to the development and impact of accounting on the modern society will always be relevant. The main conclusion that we can draw from everything stated above is that in a large part of the research, the question of how to apply the elements of the accounting method to the changes in regulatory acts is still

debatable. The stumbling block for accountants is still the correct determination of the valuation of a given object, and perhaps for this reason the leading problem in scientific research and debates relates to the correct application of valuation as a method in order to represent accounting information accurately and correctly. Each new economic object that is distinguished in accounting must be correctly valued, and presented in value in the financial statements. The first books on accounting precisely emphasized how to present this accounting object using double entry and what valuation to derive from it, so that it is presented in value and quantitatively, i.e. to have a complete material economic form.

With the retrospective approach that we applied, we established that for a long time accounting has no longer been primitive, but has entered a new phase of modern development. We cannot determine at what pace and dynamics accounting will develop, but we can accurately conclude that today's accounting is different from the accounting of the 15th century, however the basic rules have been preserved and have been passed on to new generations over the centuries. This means that there is a sequence in the development of accounting, it is not chaotic and it changes according to the permissible norms and principles. The retrospective approach has limited application possibilities and it is difficult to apply mathematical methods to it, and for this reason, the relevant hypotheses are proved with precisely defined facts and data from the research itself, i.e. qualitatively, not quantitatively.

The contributions of this article are many. Namely, for the first time the emphasis is placed on the general change in the accounting method over the years. A large part of the scientific research of the period from 1990 to 2024 is aimed at studying the current accounting objects and problems in accounting, and is not aimed at searching for the cause-effect relationship between the elements of the accounting method. This limits the scientific research itself. Double-entry bookkeeping is not directly studied together with the valuation – usually, the two issues are studied separately, which results in the incomplete form and content of some scientific works.

We hope that our article has raised many questions for our readers to think about, since the accounting matter is endless, as is its history. Every fact can lead you to something new and reveal something new, and it is only necessary to discover, find, and correctly apply it.

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GEN Z SPEAKS: UNCOVERING THE REAL FEEL OF VOICE SEARCH

Ana PUŠIĆ Katija*, VOJVODIĆ**, Marino STANKOVIĆ***

With voice search technology rapidly gaining momentum and emerging as a strong alternative to traditional search methods, this study aims to examine how Generation Z - known for their technological savviness, open-mindedness and readiness to adopt new innovations - engages with and experiences voice search. Given that Gen Z is often the first cohort to embrace cutting-edge technologies, it is particularly relevant to explore their real-life interactions with voice search so as to uncover insights about their preferences, as well as ease of use and satisfaction. The primary goal of this study is to gain insight into the voice search experience, rather than just its perceptions, and thus provide the basis for developing a model that measures real-time voice search experiences. The results have the potential to refine a voice search design tailored to the dynamic needs of Gen Z, and provide actionable insights for developers and marketers to better align voice search functionalities with young users' behaviours and preferences. Ultimately, this study seeks to establish voice search as a practical, adaptable tool that seamlessly integrates into Gen Z's fast-paced, multitasking-driven lives, creating a more intuitive and responsive digital experience. In order to achieve this, the study employs an experimental design in which participants actively use voice commands in a controlled setting, immediately followed by a comprehensive questionnaire designed to capture their satisfaction, ease of use, and

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overall experience with the technology. This approach leverages a mixed methodology, blending direct user experimentation with survey responses to provide a well-rounded understanding of how voice search works as a practical tool. The focus is on the technology's suitability for hands-free multitasking, its effectiveness as a search solution, and its ability to meet Gen Z's expectations for a convenient, efficient technology. The study fills a critical gap in previous research by providing insight into the essential elements of voice search: practicality, functionality (in terms of multitasking) and personalized search experience. The results indicate that Generation Z perceives voice search as highly practical, with Ease of Use emerging as the most positively rated factor, followed by its multitasking capabilities. However, Personalized Search Experience received neutral ratings, suggesting that there is room for improvement in creating a more engaging and tailored voice search interaction. While previous literature has highlighted these three factors as potential competitive advantages of voice search, this study gathers real-time feedback on the relevance of these factors in actual usage contexts. In this way, it provides a nuanced understanding of their value to Generation Z and makes an important contribution to the studies on voice search.

Keywords: *Voice search experience, Generation Z, voice search usability, voice search functionality, consumer behaviour*

JEL classification: *M31, D91, L86*

INTRODUCTION

Searching the internet hands-free, spelling-free, in a fast, simple and above all practical manner, just a voice away – that must be the ideal way to search the internet, and what generation other than Generation Z could fully embrace this? But is this really the case? Much has been said about Generation Z, for example, that it is a generation that does not know the world without the internet (Alruthaya, Nguyen & Lokuge, 2021), that it uses smartphones throughout the day, thus replacing traditional learning systems (Chan & Lee, 2023), and that it also exudes specific buying habits compared to other generations (Than-gavel, Pathak & Chandra, 2019). On the other hand, voice search technology is increasingly being integrated into customers' everyday lives, from search and product assistance to providing unique experiences (Minsky, Westwater, Westwater & Fahey, 2023), with voice commerce - a subset of e-commerce - being

the latest technology to use voice commands to search for products online (Kumar, Srinivas, Krishna, Sheorey & Joshi, 2022).

However, there is still insufficient research on what Generation Z actually experiences in terms of voice search and how they perceive it. Moreover, research on voice search mostly focuses on the respondents' perceptions and/or past experiences, implying a temporal gap between the actual experience with voice search and the expression of opinions about it (Moriuchi, 2019; Alhashimi, 2020; Pal & Arpikanondt, 2021; Martell & Seifried, 2024). The aim of this paper is to bridge several scientific gaps within voice search studies by focusing primarily on Generation Z and their actual experiences with voice search in real-time and real-world contexts. It should be emphasized that this study is a continuation of a conceptual paper that aimed to identify the key elements of voice search, which were to be the elements of practicality, hedonism and a personalized search experience (Hordov, Stanković & Pušić, 2024). Accordingly, this paper will begin to apply the theory in practice and will show whether Generation Z believes that the aforementioned elements can indeed be attributed to voice search. This is done by applying a mixed methods approach, starting with an experiment in which members of Generation Z used voice search in a simulated real-life situation and immediately afterwards had to record their experiences with voice search.

The elements of voice search evaluated in this study are Practicality (represented by Ease of Use and Speed and Usefulness), Multitasking, and Personalized Search Experience (represented by Hedonism, Satisfaction and Personalization). The study involved 112 Generation Z respondents who generally found all of the above elements of voice search to be positive, with the Ease of Use factor standing out in particular. This paper is divided into five parts, namely introduction, literature review, methodological approach, research results, and conclusion which includes recommendations for future research. Generation Z has been surrounded by the internet and technology from birth, so the notion of adopting buying and product search habits is unlikely to be too much of a challenge for them. However, it is certainly useful to see what stage they are currently at, and where brands can fill the gaps in the online search for products and services in order to stand out from the competition.

LITERATURE REVIEW

As the focus of this paper is on examining the experience of voice search, the literature review presented here includes studies that have directly or at

least partially examined the participants' previous experiences with voice search and/or their perceptions of it. In studying the following body of research, it became evident that there is a need to conduct a study that focuses on the actual experience of voice search that takes place in a real-world scenario and is accompanied by real-time feedback from respondents. Furthermore, as voice search has already been recognized as a useful search tool, it is essential to gather the fresh experiences of Generation Z, the individuals who can certainly use all the benefits of voice search to their advantage. An overview of the research conducted to date follows in chronological order.

Voice search has been recognized as a practical tool for hands-free internet search that effectively illustrates the multitasking advantage, as highlighted by Guy (2016). The same author emphasized the importance of incorporating a voice-based presentation of results into search systems so as to enable a fully hands-free user experience. Furthermore, the results suggest that voice search can be seamlessly integrated into various everyday scenarios, as it eliminates the need for visual attention or the traditional way of searching by typing. Authors Han and Yang (2018) investigated the role of satisfaction in the use of intelligent personal assistants and found that it has a significant positive impact on the intention to use them continuously. Specifically, they found that satisfaction is a direct predictor of a user's decision to maintain usage, with higher levels of satisfaction increasing the likelihood of continued engagement. In this context, satisfaction served as an indicator of success of the technology from the user's perspective, and encompassed both the functional capabilities of the intelligent personal assistant and the emotional dimension of the relationship it fostered. The authors Kraus, Reibenspiess and Eckhardt (2019) compared customer satisfaction between e-commerce and voice commerce, and found that convenience had a significant impact on customer satisfaction in both types of commerce, especially in voice commerce. They also proved that the efficiency of the transaction process is of utmost importance for customer satisfaction in voice commerce.

A study conducted by Dubiel (2018) explored how implementing human features in voice search systems can improve their usefulness, finding that respondents favoured systems with human features, but at the same time expressed divided opinions on how much extra effort the system should put in (by asking more questions, etc.). Voice search also proved significant in a study by Dou, Qin, Wang and Zhao (2019), which sought to identify usability issues among older people using smart TVs, with voice search providing the best user experience. Authors Nguyen and Prybutok (2019) investigated the importance of perceived usefulness, perceived ease of use and perceived fun when us-

ing voice-user interfaces, with male respondents showing greater sensitivity to perceived ease of use. The latter suggests the importance of working on the personalization of voice search, as this research has shown that men and women may have different experiences when using voice search. Perceived ease of use and perceived usefulness of voice assistants were the focus of Moriuchi's 2019 study, which included respondents who had previous experience with transactional and non-transactional activities, with both factors proving significant for voice search experience and intention to use again. A study conducted by Alagha and Helbing (2019) focused on the quality of voice assistant responses, with the authors themselves conducting an experiment to test the accuracy of voice search using frequently asked questions from individuals in relation to health topics. Although the aforementioned study did not include a specific population, but the researchers themselves tested voice assistants, this study showed elements of an experiment conducted in real time. A review of the existing theories on the consumer decision-making process supported by voice assistants, provided by Dellaert, Shu, Arentze, ... and Steffel (2020), suggests that voice assistants have the potential to significantly influence the consumer decision-making process, with changes in perception, mental models and decision-making strategies at the forefront. Alhashimi's (2020) study, which relied on respondents' previous experiences of using voice recognition technology, showed that the hedonic features of voice recognition technology are associated with the frequency of its use by Generation Z. In addition, the aforementioned study found that Generation Z uses voice recognition technology for entertainment and functional purposes.

A broader framework for understanding the acceptance of voice assistant technology was provided by Pal and Arpnikanondt (2021), who found that information and system quality significantly influenced satisfaction in the use of voice assistants, while privacy concerns were not found to be significant. The use of voice-activated smart home devices was the subject of observation by Canziani and MacSween (2021), with hedonism and perceived usefulness proving to be the strongest predictors of online ordering via such devices. Research conducted by Pal, Roy, Arpnikanondt and Thapliyal (2022) on the antecedents of respondents' intention to use voice-based consumer electronic devices found that functional aspects and social perceptions played an important role in building trust in such devices, while hedonic characteristics and perceptions of privacy were not as influential. In addition, the authors Mehta, Verghese, Mahajan, ... and Dedyukhina (2022) examined the factors influencing the use of conversational commerce based on messenger chatbots and found that trust, ease of use and usefulness of chatbots proved to be ex-

tremely important. A study by Liu, Wan, Zou and Zhang (2023) examined the factors influencing respondents' willingness to use voice assistants while driving, and found that personalization and satisfaction with search results had a positive impact on the overall experience of using voice assistants. Faruk, Funilkul, Mongkolnam and Pal (2023) presented a study in which they investigated the influence of previous experiences with voice search on users' preferences. They conducted an experiment with 24 respondents, half of whom had previous experience with voice search. Experience proved to be important for the overall user experience, although no clear conclusions could be drawn as the sample was very small. The study by Kautish, Purohit, Filieri and Dwivedi (2023) examined the role of the wow effect on users' purchase intentions in the context of voice assistants when shopping online. The main findings suggested that the functional, hedonic, social and cognitive dimensions significantly influence user experience, while the wow effect plays a key role in stimulating positive word of mouth and purchase intention. Ahn's (2023) study included respondents who already had experience with voice search and confirmed that the perceived usefulness of voice search, its ease of use and associated satisfaction were the key factors in predicting future intentions to use voice search.

Calahorra-Candao and Martín-de Hoyos (2024) pointed out the main predictors of voice assistant adoption in online shopping, with enjoyment, expected performance, ease of use and perceived usefulness standing out as the most important factors. Regarding the drivers of purchase intent when using tools supported by artificial intelligence, the authors Corbos, Mis, Triculescu, and Trifu (2024) recommend that companies should adopt voice recognition and personalization of results to increase purchase intent, as the latter have been shown to be important factors. Arachchi and Samarasinghe (2024) analysed the impact of mobile speech recognition technology attributes on purchase intention and found that Generation Y was more inclined to adopt innovative technologies than Generation X, and that perceptions of usefulness, ease of use and enjoyment were important influencing factors. This can be interpreted to mean that it is important which generation is the focus of voice search research, and that younger generations can be expected to show a greater tendency to use voice search than the earlier ones.

Building upon the existing studies on voice search usability, multitasking functionality, and personalization (Moriuchi, 2019; Nguyen & Prybutok, 2019; Han & Yang, 2018), this study seeks to address the following questions: How does Generation Z perceive the practicality of voice search in terms of ease of use and speed? To what extent does voice search support multitasking for Generation Z users? How do users experience personalization in voice search,

particularly in terms of engagement (hedonism), satisfaction, and perceived customization? What elements of voice search contribute most to Generation Z's overall experience, and what areas need further improvement?

METHODOLOGY

Considering the previous studies on voice search and the way they conceptualise the respondents' experiences with voice search, it was concluded that a mixed methods approach was best suited to determine Gen Z's real voice search experiences. More specifically, an experiment was conducted with students of the Faculty of Economics and Business at the University of Dubrovnik, who were given the task of voice searching three phrases in five minutes, while at the same time trying to transcribe the displayed text as much as possible. In this way, the real-life scenario in which students find themselves on a daily basis (using cell phones for their own purposes during class) was simulated. The experiment was not announced to the students, but a sudden walk-in classroom approach was used, where classrooms were selected that were known to be attended by Gen Z students.

Before conducting the main study, a preliminary test was performed with a smaller group of students in order to assess whether there were any significant differences in voice search performance and results between iPhone and Android users. The test included an equal number of students using both types of devices. The test found no noticeable differences in the search process or the results displayed across different voice assistants. Additionally, the study included students from both undergraduate and graduate studies, all of whom belong to Generation Z. This ensured that the sample aligns with the study's target population.

The phrases that the students were asked to search for using voice search were the following: a) *Comparison of the latest Samsung and iPhone smartphones*, b) *Dubrovnik-Cavtat bus timetable* and c) *Black Friday laptop deals*. At the same time, the text that the students were asked to transcribe was shown (a text about Coca Cola's marketing strategies), and they were further instructed to search for these phrases and look at the results, but to try as much as possible not to stop copying the text. When selecting search phrases, care was taken to ensure that at least one phrase included well-known brands (e.g. iPhone and Samsung), and a service provider (the local bus company Libertas is a symbol of public transportation in Dubrovnik, so a suburban line was chosen), and a phrase that represented a relevant consumption period (Black Friday was cho-

sen as this study was conducted in November, when Black Friday deals were announced at the beginning of the month). The Coca Cola marketing strategy was chosen for the text that the students were asked to copy, because the students would spend too much time reading a more complicated text, therefore they had a topic in front of them that they were relatively familiar with and it was assumed that it was not unclear.

After completing the task, the students were shown a QR code that led them to a questionnaire (Google form) the aim of which was to investigate their experience using voice search. Completing the experiment in this way allowed for real-time feedback under controlled conditions, so that new impressions could be captured. The questionnaire contained statements that students could rate on a 5-point Likert scale with a neutral option, where 1 stood for “I strongly disagree” and 5 for “I strongly agree”. The questionnaire was structured so that the element of practicality was measured by the aspects of 1) *Ease of Use* (7 items) and 2) *Speed and Usefulness* (5 items), functionality was represented by the aspect *Multitasking* (5 items), while the element of personalized search experience was measured by the elements of 1) *Hedonism* (6 items), 2) *Satisfaction* (4 items) and 3) *Personalization* (5 items). The items for the aspects of practicality were adopted from Venkatesh and Davis (2000) and Chen and Florence (2021), multitasking was measured according to Doolittle, Wojdak, Watson, Adams and Mariano (2024), while the items for personalized search experience were adopted from Kautish, Purohit, Filieri and Dwivedi (2023), Canziani and MacSween (2021), Han and Yang (2018) and Chen and Florence (2021). A list of all statements can be found in the appendix to this paper.

RESULTS

Since this study is only the first step in an effort to put the findings from the literature and previous work into practice, basic descriptive statistics for the observed elements of voice search are presented here. This was primarily done to get Generation Z’s impressions of the real-world experience regarding voice search, and to see how these elements can be improved for future research, as well as in a practical sense. As shown in Table 1, the gender distribution in this study revealed a higher proportion of female participants compared to males, with a negligible proportion of respondents choosing not to indicate their gender.

Table 1: Respondents' descriptive statistics

Gender	Frequency	Percent	Valid Percent	Cumulative Percent
Male	39	34.8	34.8	34.8
Female	72	64.3	64.3	99.1
Do not wish to say	1	.9	.9	100.0
Total	112	100.0	100.0	

Source: Authors

As explained earlier, the element of practicality in this study is represented by the aspects of Ease of Use and Speed and Usefulness, with the results in Table 2 showing moderately high scores for Ease of Use (mean = 3.69) and predominantly positive scores for Speed and Usefulness (mean = 3.46). These results indicate that the voice search system meets the basic expectations of the respondents in terms of functionality and usability. However, the variability of the responses shows potential for improvement, particularly in terms of optimizing speed and tailoring usefulness to align with the needs of Generation Z.

Table 2: Ease of Use and Speed and Usefulness statistics

Mean	Ease of Use	Speed and Usefulness
Mean	3.6939	3.4625
Median	3.7143	3.600
Mode	3.71	3.60
Std. Deviation	.82854	.94040

Source: Authors

In terms of the benefits of voice search for multitasking, the results in Table 3 indicate that Generation Z voice search technology provides moderate support for Multitasking (mean = 3.56), with most participants finding it generally helpful for completing multiple tasks simultaneously (in this particular case, transcribing the text during voice search).

Table 3: Multitasking statistics

Multitasking	
Mean	3.5696
Median	3.6000
Mode	4.00
Std. Deviation	.85285

Source: Authors

The results presented in Table 4 indicate that respondents expressed moderately neutral opinions with regard to the Personalized Search Experience, as seen in the mean values for Hedonism (mean = 3.16), Satisfaction (mean = 3.24), and Personalization (mean = 3.20). These scores suggest that, on average, respondents neither strongly agreed nor strongly disagreed with the provided statements. This neutrality may indicate that while voice search offers a certain level of personalization and enjoyment, it does not yet deliver a highly tailored or engaging experience that significantly resonates with users. This finding highlights an opportunity for further refinement in personalization features that would ensure a better adaptation of voice search to individual user preferences, and enhanced satisfaction.

Table 4: Personalized search experience statistics

	Hedonism	Satisfaction	Personalization
Mean	3.1592	3.2455	3.2036
Median	3.1667	3.2500	3.2000
Mode	3.00	4.00	3.40
Std. Deviation	.84077	.99264	.86991

Source: Authors

Observing the results as a whole, it can be said that in all three observed areas of voice search, there are areas where Gen Z’s experience of conversational search can be improved in the future, with the area of practicality proving to be the most positive aspect of voice search in this particular case. The research results indicate that Generation Z perceives voice search as functional and practical, particularly in terms of ease of use and multitasking support. However, the neutral stance on personalization and hedonism suggests that voice search does not yet provide a fully engaging or tailored experience. This could imply that current voice search technology lacks sufficient adaptability to individual user preferences, limiting its potential to become a preferred search method beyond utilitarian use.

CONCLUSION

The adoption of new technologies and a modern approach to everyday activities is probably nothing new for Generation Z, as has already been shown several times in various areas of consumer studies. However, the question aris-

es as to whether this applies to every novelty offered to consumers, and to what extent this generation is really susceptible to establishing and accepting new trends in consumer behaviour. With this in mind, this paper provided an initial insight into Generation Z's real-life experience of modern voice technology-enabled search on the internet, and drew several conclusions. By placing voice search in the real-life conditions of Generation Z, practicality in the form of Ease of Use proved to be the most important element of voice search. In addition, as a representative of the voice search functional nature, multitasking proved to be a useful feature, considering that respondents overwhelmingly recognized voice search as a multitasking tool. Of course, it should be emphasized that this study provided a specific context in which the ability to perform multiple tasks using voice search was investigated, although according to these results, it can be assumed that Generation Z will be able to multitask in some other life situations by using voice search.

A somewhat less considered factor of voice search - the personalized search experience, viewed through Hedonism, Satisfaction and Personalization, opens the door to new questions and possibilities for voice search research. Some examples include the following: how to increase Generation Z's enjoyment and satisfaction when using voice search, what do they find satisfying when using this type of search, and what factors in voice search are critical to making the experience enjoyable. Of course, the search satisfaction aspect also depends on brands, which can use these insights to adapt keywords, communication tone and content formats to Generation Z's expectations and preferences. The latter implies efforts aiming to better personalize search results, all with the goal of making voice search a pleasant alternative to traditional search tools. In addition, these represent opportunities for brands to increase engagement through personalized recommendations, promotions and hands-free features, which will enable them to stand out from the crowd and become more competitive.

For tech developers and marketers, these findings highlight the need to enhance personalization and user engagement in voice search systems. Developers should focus on improving context-aware interactions, more natural conversational flows, and customized content recommendations in order to increase satisfaction and enjoyment. Marketers, on the other hand, can leverage voice search optimization by tailoring product descriptions and keywords so as to align with how Gen Z formulates voice queries, thus making voice search a more effective tool in digital marketing strategies.

While this study offers valuable insights, several limitations should be noted. First, the study was conducted within a controlled classroom setting, which, while useful for consistency, may not fully reflect diverse real-world

voice search behaviours across different contexts (e.g., at home, while commuting). Second, although the sample includes undergraduate and graduate students falling within the Gen Z cohort, a wider sample across different backgrounds could provide a more comprehensive view. Third, this study focused primarily on functionality and user perception, meaning future research could explore additional aspects such as privacy concerns, comparison with typing, the potential impact of voice messaging experience on voice search adoption, intention to use voice search again and potentially make a purchase using voice search technology. This research is only the first step in putting theoretical knowledge about the adoption of voice search technology into practice, making it an exploratory study and a basis for further research into Generation Z's experience of voice search. As this is a continuation of a conceptual paper on voice search, which explored three elements of voice search that have been shown to be significant in the literature, it is recommended that research be extended to other elements of voice search. Overall, the results of this study suggest a generally positive experience with voice search when it comes to Generation Z, with plenty of room for improvement, which should not go under the radar for brands.

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APPENDIX

PRACTICALITY

1. Ease of Use

- I find the voice search function easy to use.
- The voice search feature is simple to navigate.
- Interacting with the system does not require a lot of my mental effort.
- My interaction with the voice search system was clear and understandable.
- I find it easy to get the system to do what I want it to do.
- Voice search makes surfing easy to use and effortless.
- Overall, I find voice search to be a simple search tool.

2. Speed and Usefulness

- It is quick to browse the internet using voice search.
- Voice search allowed me to accomplish the task with no time wasted.
- I find that voice search can help me be more productive.
- Voice search saves time when browsing in general.
- Overall, I find voice search to be a quick and useful search tool.

Functionality

1. Multitasking

- Voice search allowed me to perform tasks simultaneously.
- Voice search helped me browse the internet without using my hands too much.
- Voice search enabled me to perform tasks even when I am physically occupied (searching the internet and copying the text).
- Multitasking is a key motivating factor for using voice search.
- Overall, I think voice search is a good multitask tool.

Personalized Search Experience

1. Hedonism

- Voice search technology makes my web browsing experience interesting.
- It is fun to use voice search for web browsing.
- Using voice search seems to give me a sense of enjoyment.
- Voice search technology is exciting.
- Voice search technology is convenient for me.
- Overall, I find enjoyment in using voice search.

2. Satisfaction

- I am satisfied with the results I got from voice search.
- I find that voice search effectively met my internet search needs.
- I was satisfied using voice search for browsing the internet and completing tasks.
- Overall, I am satisfied with the quality of the voice search service.

3. Personalization

- Voice search makes me feel like it understands and listens to me as a unique customer.
- Voice search helps to find information or products that match my personal preferences.
- Voice search makes me feel like the search results are tailored specifically to my needs
- I feel that, over time, the more I use voice search, the more precise and personalized the search results would become.
- Overall, I find voice search to be a way to personalize the search experience.

NETWORK ANALYSIS OF LIFE AND NON-LIFE INSURANCE PREMIUM GROWTH PATTERNS ACROSS EU AND EEA COUNTRIES

Silvija VLAH JERIĆ*, Jakša KRIŠTO**, Maja MIHELJA ŽAJA***

This paper investigates the interconnectedness of gross premiums written for life and non-life insurance across countries of the European Union and European Economic Area using a network analysis approach. Quarterly data from 2016 to 2024 are used to calculate correlation matrices, following two approaches. The first approach is using the premium log growth directly for calculating correlations. The second one uses partial correlations, i.e. correlations calculated on values obtained after removing the market factor and country-specific trends. The analysis showed that non-life insurance exhibits initially strong correlations driven by seasonal patterns and short-term shocks, which weakened significantly after removing global and local effects. In contrast, life insurance correlations are initially lower, then decrease moderately after factor removal, and remain more stable.

Based on the partial correlation matrix, networks for both non-life and life insurance gross written premiums are constructed. The analysis reveals the difference between structures and topology of non-life and life insurance networks. The non-life insurance network appears to be more fragmented, with fewer cross-country connections and prominent concentrations of strong correlations. In comparison, the life insurance network appears to be more stable, with connections fairly scattered throughout countries. The higher interconnectedness demonstrates the persistence of shared long-term structural drivers, such as demographic trends, regu-

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latory frameworks, and financial market integration, which continue to have an impact even after factor removal.

This study adds to the developing subject of financial network analysis by providing a thorough comparison of life and non-life insurance networks in the EU. The findings have practical implications for policymakers and industry stakeholders, underlining the importance of strengthening insurance market structures and increasing resilience to the changing economic and risk landscapes.

Keywords: *Life insurance, non-life insurance, network analysis, correlation structures*

JEL classification: *G22, C45, C22*

INTRODUCTION

Understanding systemic resilience and vulnerability requires examining the relationships between the insurance industry and financial markets. Financial networks can increase fragility by spreading shocks among interconnected organizations, but they can also absorb shocks to improve stability. Depending on the data available and the underlying economic activity, different approaches are usually used to assess the interconnectedness of the financial markets. One of the approaches is using network analysis, which stems from graph theory, an area of mathematics.

Broadly speaking, a network is a system of vertices connected by edges, and network analysis consists of calculating and examining network measures such as density, clustering coefficient, etc., which help in discovering network topology. It proved to be a useful tool for analysing complex systems, since behind every complex system there is an intricate network that encodes the interactions between the system's components. There are many areas of applications found in the literature, such as social networks, power grid, trade network, or finance networks (Soramäki, 2007; Giudici et al., 2019; Pitoski, 2020; Alexander, 2024; Labini et al., 2025).

The goal of this research is to shed light on the interdependencies in the insurance market within the countries of the European Union (EU) and European Economic Area (EEA). By examining and comparing the non-life insurance network structures and sectors through network analysis, this research explores the underlying patterns influencing insurance gross premium growth. The bottom line of the idea is to construct an insurance network based on

country correlations and partial correlations, and observe the distinctive properties of non-life and life insurance networks.

With an emphasis on variations in network topologies and the variables that influence their interconnection, the research question focuses on understanding how market-wide and nation-specific factors impact the structural characteristics of insurance networks in connection to systemic stability and regional integration, as well as how observed correlations across nations are shaped. The hypothesis is that their network structure is more fragmented than that of life insurance premiums, relating to their reliance on short-term shocks and region-specific hazards. Furthermore, life insurance premiums should show a greater degree of interconnection after adjusting for country-specific and market-wide impacts, demonstrating the enduring nature of long-term structural factors. Additionally, it is expected that important network characteristics including connectedness, centrality, and clustering would highlight structural variations between the two insurance industries, offering insights into their unique market dynamics.

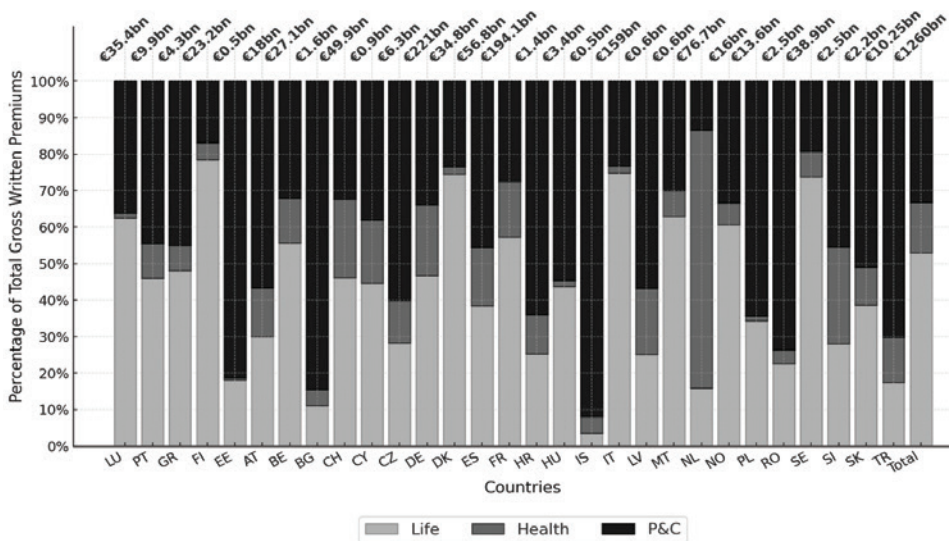
This paper is structured as follows. After the introduction, the background and literature review provide an overview of the existing research on network analysis in the financial sector. The methodology section describes the analytical framework used to construct and analyse the correlation networks of life and non-life insurance premium growth. The results section presents the key findings, comparing network metrics and structural differences between the two sectors. Finally, the conclusion summarizes the study's implications, discusses the limitations, and offers recommendations for future research.

BACKGROUND AND LITERATURE REVIEW

The European insurance market consists of economically, culturally, and regulatorily diverse countries. Analysing the differences in gross written premiums (GWP) between life and non-life insurance across EU countries requires examining the structure, dynamics, and influencing factors of both sectors. Figure 1 shows the gross written premium per country in 2020, split by line of business: Life Insurance, Health Insurance and Property and Casualty Insurance (P&C). The labels above the bars show the total gross written premium per country in billions of euros. It is visible that in countries such as Finland, Denmark, Sweden, France, and Italy the life insurance tends to dominate. Life insurance is often associated with savings and investment behaviours linked to income levels and financial literacy (Dragos et al., 2020;

Rey-Ares et al., 2023). In contrast, non-life insurance is primarily connected to asset protection, compliance with regulatory requirements (such as motor insurance), and cultural attitudes towards risk, mainly driven by growth in property and health insurance (Sihem, 2024). Demographic trends, particularly the ageing populations in countries like Germany and Italy, contribute to increased demand for life insurance products such as pensions and annuities (McCarthy & Mitchell, 2004; Vanella et al., 2022). Overall, Western European countries exhibit a predominance of life insurance due to mature markets and demand for savings-linked products. In contrast, non-life insurance is more prominent in Eastern Europe, driven by regulatory frameworks for motor insurance and a lower demand for life insurance. Southern Europe highlights a preference for life insurance, often tied to cultural inclinations towards savings products that offer guaranteed returns.

Figure 1: Gross written premium split by line of business, per country, in 2020

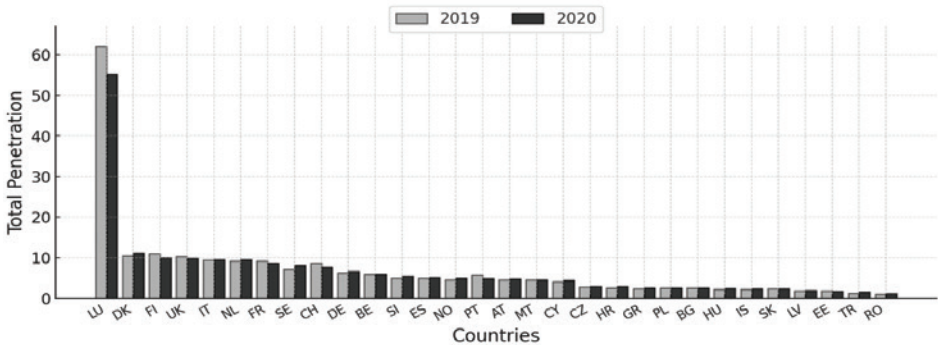


Data source: Insurance Europe

Insurance penetration is the ratio of total insurance premiums to a country's GDP (Rejda & McNamara, 2021), which indicates financial protection for individuals and businesses against unexpected losses, such as natural disasters, health crises or accidents. As such, it is a critical indicator for assessing the role of insurance in an economy, i.e. the level of development of the insurance sector in a country. Figure 2 shows the insurance penetration by country for

the years 2019 and 2020. The average penetration rate across all countries was 9.5% in 2019, decreasing to 6.8% in 2020.

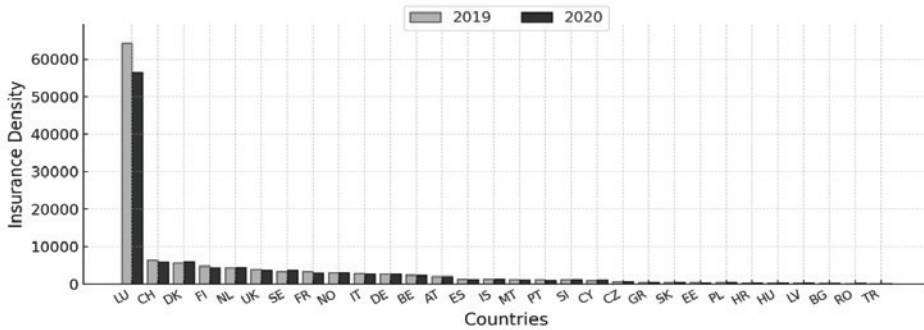
Figure 2: Insurance penetration rate per country for 2019 and 2020 (in %)



Data source: Insurance Europe

Insurance penetration tends to be higher in wealthier nations like Luxembourg, Denmark and the Netherlands, where greater awareness of risk and affordability complements widespread savings products and tax-advantaged life policies. Due to limited disposable income and lesser awareness of insurance options in Eastern Europe, the penetration rates are noticeably lower there. Alongside insurance penetration, another important indicator for assessing the development and accessibility of an insurance market is insurance density. It focuses on the extent of insurance consumption at the individual level, i.e. it measures the average premium per capita in a given country (Rejda & McNamara, 2021). Insurance density by country for the years 2019 and 2020 is shown in Figure 3. The average density across all countries was €2187 in 2019, decreasing to €2093 in 2020.

Figure 3: Insurance density per country for 2019 and 2020 (in euros)



Data source: Insurance Europe

Countries like Luxembourg, Netherlands, and the Scandinavian countries display a high level of insurance density, reflecting individuals' financial capability to invest in insurance and highlighting the market's ability to cater to diverse consumer needs. The variations in gross written premiums (GWP) between life and non-life insurance across EU countries and the differences in insurance penetration and density reflect the distinct economic, cultural and regulatory contexts. Life insurance is dominant in wealthier, ageing populations, while regulatory requirements and comprehensive risk coverage need influence the non-life insurance share.

Numerous papers use network analysis in different aspects of the financial sector to provide valuable insights into network resilience and improve the understanding of the sector's interconnectedness and influence on systemic stability. In the context of the insurance industry, researchers predominantly focus on examining systemic risk and the interconnections among financial institutions, as well as between insurance and reinsurance entities. Hasse (2022) made an empirical analysis of the European financial system and explored the systemic risk within financial networks through a network-focused approach. In his paper, he introduced an innovative metric for systemic risk that focuses on interconnectedness among financial institutions. This metric takes into consideration both direct and indirect connections among financial institutions, since it relies on the structural framework of the financial network. Indirect connections are underlined due to their significance during times of crisis and their role in identifying the most vulnerable institutions, which is particularly vital for monitoring the financial system's stability. In the paper by Kotlicki (2022), the network structure and systemic risk present in the UK reinsurance

sector were examined, utilising data from 2016 in accordance with Solvency II regulations. The findings showed that the UK reinsurance market displays both “scale-free” and “small-world” characteristics, featuring a core-periphery structure. Prominent reinsurers function as hubs that facilitate the transfer of risk. The network demonstrates resilience to random shocks; however, it is susceptible to the failure of critical hubs. High local clustering mitigates the risk of a domino effect, while shorter paths between nodes can accelerate the spread of losses. The document analyses macroeconomic shocks and the potential failures of key insurers. The findings indicate that systemic risk remains limited, with losses primarily being localised. Overall, the results of this paper support the notion that, despite its complexity, the reinsurance market does not significantly threaten financial stability due to its fragmented and diversified exposures.

The intricate dynamics of systemic risk within financial networks were analysed by Bougheas and Kirman (2014). The paper emphasized how financial shocks can propagate through the connections between institutions. It was proven that the impact of these shocks is heavily influenced by network topology and the distribution of risk among participants. According to the authors, network structures such as density, connectivity and hierarchy play a crucial role in shaping the system’s resilience against such shocks. In order to enhance conventional risk assessment methods, the paper advocates incorporating network analysis tools. Empirical evidence reveals that national and international payment systems are hierarchical, with specific key hubs recognised as “too big to fail”. The authors argue that clusters of institutions that become “re-connected” can pose substantial threats to the stability of the entire financial system. In their paper, Jackson and Pernoud (2021) gave a comprehensive overview of systemic risk within financial networks, emphasising two primary categories of risk – channelized externality which includes risks such as defaults, portfolio linkages and fire sales that propagate through direct connections between institutions, and feedback loops and beliefs that include bank panics and credit freezes, and arise from shifts in the beliefs of met participants. The insurance sector’s interconnectedness with financial and non-financial companies was analysed by Jourde (2022). He examined the long-term changes in the interconnectedness of the insurance sector, utilising stock return data spanning from 1973 to 2018 across 16 developed countries. A key finding of the study is that the insurance sector has become significantly more interconnected over the past decade, especially compared to related industries’ relative stability. The results revealed that the largest insurance companies exhibit connectivity levels similar to those of major banks, but are more vulnerable

to non-financial shocks than banks. Clemente and Cornaro (2022) developed a model that uses multi-layer network analysis to examine systemic risk in the insurance industry. Their study brought to light operational interdependencies impacted by outside service providers and legal constraints, as well as financial concerns such as exposure through joint investments, reinsurance contracts, and credit lines.

Kanno (2016) offers a thorough examination of the worldwide non-life reinsurance network, simulating the contagion of defaults by using the Eisenberg-Noe framework and looking at systemic risk by using network indicators. This paper, on the other hand, uses correlation networks to find regional patterns and structural differences in the interconnection of life and non-life insurance premium growth across EU nations. The information utilized to perform this study is described in the section that follows.

DATA DESCRIPTION AND METHODOLOGY

DATA DESCRIPTION

The study examines gross premiums written for both non-life and life insurance across 30 EU and EEA countries. The dataset includes quarterly data spanning from 2016 Q3 to 2024 Q1 for non-life, and 2017 Q4 to 2024 Q1 for life. This information, which includes comprehensive details on insurance premiums, claims and expenses, comes from the Solvency II templates released by EIOPA.

Preprocessing involved preparing the quarterly, non-cumulative premium data for analysis. This step ensured that the data accurately captured the short-term variations and trends without distortion from cumulative reporting. Non-cumulative data enables a clearer representation of actual premium dynamics over time, particularly for non-life insurance, which is more sensitive to seasonal effects and event-driven risks.

The descriptive statistics for gross premiums written in non-life and life insurance are presented in Table 1 and Table 2, respectively. The tables display the mean, median, standard deviation (SD), minimum (Min), and maximum (Max) values, for a dataset categorized by country. The normalized range (NRange), which represents the spread of values as the difference between the maximum and minimum divided by the mean, and the coefficient of variation (CVar), which calculates relative variability as the ratio of standard deviation to the mean, are also included. These summaries highlight the key differenc-

es in the scale, distribution and variability of premiums across the observed countries. The reported premiums represent averages calculated across all quarters and all years within the study period. This approach provides a single, representative value for premium levels, suitable for cross-country and sectoral comparisons. However, this method smooths out potential temporal trends and seasonal effects, which may contribute to the observed variability, particularly in the non-life insurance sector. For example, quarterly data inherently captures short-term fluctuations, and in non-life insurance, these are often tied to seasonal or event-driven risks, such as extreme weather or short renewal cycles. This granularity in the data amplifies observed variability compared to life insurance, which operates on longer time horizons and is less sensitive to short-term shocks.

Table 1: Summary statistics of non-life gross premiums written

Country	Mean	Median	SD	Min	Max	CVar	NRange
Austria	2623.24	2405.40	647.70	1805.72	4290.14	0.247	0.947
Belgium	4951.28	4663.62	1517.20	2971.46	8701.52	0.306	1.157
Bulgaria	332.20	328.10	93.94	144.72	514.66	0.283	1.114
Croatia	272.99	262.82	71.71	148.05	434.92	0.263	1.051
Cyprus	147.00	140.93	22.25	117.74	205.06	0.151	0.594
Czechia	1112.29	1072.72	262.72	705.76	1603.33	0.236	0.807
Denmark	2449.40	2098.97	945.22	1128.90	4201.51	0.386	1.254
Estonia	153.92	147.77	31.71	86.19	232.49	0.206	0.950
Finland	966.51	738.92	455.39	513.21	1943.72	0.471	1.480
France	24695.91	20143.64	10875.73	13245.06	49419.39	0.440	1.465
Germany	20901.49	15548.42	11201.50	10966.04	48292.42	0.536	1.786
Greece	521.46	510.28	55.69	432.96	679.97	0.107	0.474
Hungary	471.91	455.26	100.65	295.48	703.33	0.213	0.864
Iceland	138.85	108.02	80.09	63.97	441.58	0.577	2.720
Ireland	5175.31	4989.72	1676.85	3084.82	9115.21	0.324	1.165
Italy	8626.35	8439.48	1255.91	6536.65	11350.60	0.146	0.558
Latvia	112.74	107.86	26.53	42.03	178.06	0.235	1.207
Liechtenstein	358.88	335.87	148.63	167.33	814.95	0.414	1.805
Lithuania	148.10	133.25	40.53	94.96	239.52	0.274	0.976
Luxembourg	2605.50	2575.50	1404.93	650.69	5385.77	0.539	1.817
Malta	578.91	490.50	357.99	87.94	1578.28	0.618	2.574
Netherlands	15543.55	15303.22	3845.40	3346.65	25735.64	0.247	1.440

Country	Mean	Median	SD	Min	Max	CVar	NRange
Norway	1644.44	1366.23	757.27	826.90	3688.20	0.461	1.740
Poland	2451.55	2360.39	432.48	1876.18	3803.98	0.176	0.786
Portugal	1211.68	1177.48	214.38	793.58	1802.98	0.177	0.833
Romania	543.76	471.29	170.14	190.35	889.74	0.313	1.286
Slovakia	283.95	286.50	45.65	110.21	354.87	0.161	0.862
Slovenia	456.72	460.82	69.92	340.52	622.82	0.153	0.618
Spain	8656.55	7507.39	2577.13	5878.56	14932.07	0.298	1.046
Sweden	2740.46	2445.54	809.44	1825.95	4635.08	0.295	1.025
Across all countries	3695.90	881.48	6806.89	42.03	49419.39	1.842	13.360

Table 2: Summary statistics of life gross premiums written

Country	Mean	Median	SD	Min	Max	CVar	NRange
Austria	1974.94	1975.88	103.10	1799.77	2176.14	0.052	0.191
Belgium	4318.59	4322.37	493.19	3363.92	5176.68	0.114	0.420
Bulgaria	49.86	47.45	16.97	14.54	96.68	0.340	1.647
Croatia	95.52	98.02	14.64	71.55	118.95	0.153	0.496
Cyprus	113.32	108.88	28.19	77.18	174.01	0.249	0.854
Czechia	466.76	479.40	61.86	239.93	560.41	0.133	0.687
Denmark	7161.14	7201.90	942.87	5576.48	9447.12	0.132	0.541
Estonia	63.14	64.94	8.90	47.24	81.40	0.141	0.541
Finland	1191.33	1156.40	392.95	710.20	2769.31	0.330	1.728
France	42267.93	43754.89	5076.20	26596.71	54842.81	0.120	0.668
Germany	37398.83	37096.35	2349.40	32993.35	43210.45	0.063	0.273
Greece	566.73	568.03	96.23	416.13	835.96	0.170	0.741
Hungary	371.91	376.85	50.18	225.57	451.73	0.135	0.608
Iceland	12.53	12.00	2.93	8.64	19.90	0.234	0.899
Ireland	12033.34	12336.87	1680.30	8971.49	15679.37	0.140	0.557
Italy	25535.22	25781.81	2831.90	19821.74	30539.70	0.111	0.420
Latvia	25.10	24.99	14.27	9.18	83.33	0.569	2.954
Liechtenstein	601.90	432.99	372.07	91.87	1440.34	0.618	2.240
Lithuania	36.18	38.52	8.75	0.78	47.58	0.242	1.294
Luxembourg	6602.96	6622.80	1563.23	2415.50	10505.40	0.237	1.225
Malta	604.82	600.29	75.08	497.55	816.06	0.124	0.527
Netherlands	3909.34	3512.95	1048.42	2972.35	5936.11	0.268	0.758

Country	Mean	Median	SD	Min	Max	CVar	NRange
Norway	3677.03	3330.75	1502.33	1904.37	8238.34	0.409	1.723
Poland	1177.52	1167.34	109.98	993.90	1508.90	0.093	0.437
Portugal	1554.99	1594.25	430.00	644.10	2297.49	0.277	1.063
Romania	114.39	110.76	15.63	80.77	149.80	0.137	0.603
Slovakia	219.87	222.71	36.02	114.69	287.50	0.164	0.786
Slovenia	136.85	133.30	20.25	86.95	193.01	0.148	0.775
Spain	7294.00	7286.83	1533.01	4731.45	11130.94	0.210	0.877
Sweden	6153.72	6091.61	1755.35	2381.28	8956.14	0.285	1.068
Across all countries	5524.33	855.24	10595.45	0.78	54842.81	1.918	9.927

Non-life insurance premiums often demonstrate higher averages and greater variability compared to life premiums. For example, Belgium's non-life premiums average €4,951.28 million, surpassing its life premiums of €4,318.59 million. Similarly, Austria's non-life premiums average €2,623.24 million, exceeding its life premiums of €1,974.94 million. Croatia follows this trend, with non-life premiums at €272.99 million compared to €95.52 million for life insurance. These patterns highlight the localized and short-term nature of non-life insurance products, which are closely tied to region-specific risks.

One feature that distinguishes non-life insurance is its variability. For instance, in Austria, the non-life sector's coefficient of variation (CV) is 24.7%, which is much higher than the life premiums' CV of 5.22%, with a standard deviation of €647.70. Belgium also shows a CV of 11.4% for life insurance and 30.6% for non-life insurance. Croatia's life insurance CV of 15.3% is once again surpassed by its non-life premiums, which show a CV of 26.3%. These higher CVs highlight how non-life insurance is more vulnerable to outside shocks, like natural disasters and changes in regulations, which have a disproportionate impact on premium levels. Furthermore, non-life premiums frequently have greater normalized ranges. The non-life premiums in Bulgaria, for example, range from €144.72 to €514.66, with a normalized range of 1.11. Bulgaria, on the other hand, has a wider normalized range of 1.65, with life premiums ranging from €14.54 to €96.68. Despite being more stable in many markets, this difference suggests that life insurance prices in Bulgaria can vary significantly in smaller or less developed markets.

Despite being more stable overall, life insurance premiums are continually expensive on average in the majority of countries because of the policies' high value and extended duration. The average life insurance premium in Austria is €1,974.94 million, with a standard deviation of €103.10 (CV = 5.22%), in-

dicating stable market conditions and little relative volatility. The average life insurance premium in smaller markets, such as Croatia, is €95.52 million, with a CV of 15.3%, indicating a moderate degree of relative variability. The life insurance CV of 34.0%, the highest among the nations under analysis, is reported by Bulgaria, a smaller and less developed market, suggesting instability in this market.

With larger CVs and wider normalized ranges in the majority of the markets, non-life insurance continuously exhibits more variability than life insurance. For example, the CV for non-life insurance in Belgium is 30.6%, whereas the CV for life insurance is 11.4%. Similarly, the CV for Austria's non-life premiums is 24.7%, whereas the CV for life premiums is only 5.22%. However, some market dynamics may reverse these tendencies in some circumstances, as evidenced by exceptions such as Bulgaria, where life insurance has a higher normalized range (1.65), compared to non-life insurance (1.11). These findings highlight how localized hazards and market dynamics influence the variability of non-life insurance, whereas life insurance typically corresponds with more stable, wider demographic and economic characteristics.

METHODOLOGY

The methodological framework combines time series transformations and network analysis to evaluate the interconnectedness of life and non-life insurance premium growth across countries.

Premium growth was measured using logarithmic changes so as to stabilize variance and enable cross-country comparisons. In order to isolate intrinsic relationships, the market-wide growth factor and country-specific trends were removed. This ensures that correlations reflect structural linkages rather than shared global or country effects.

The process adjusted the one proposed by Xu et al. (2022). First, a *market factor* was calculated, which was the mean quarterly premium growth for all of the countries under analysis. This element captures systematic movements that impact all markets and indicates the overall trend in premium increase. Using the market as an external regressor, a *Seasonal Auto Regressive Integrated Moving Average (SARIMA)* model was fitted to each country's growth rates. This method guarantees that wider market factors are considered. The seasonal component accounts for quarterly patterns in premium growth, which are especially relevant for non-life insurance. The residuals were extracted after the SARIMA model was fitted. *The idiosyncratic, country-specific growth*

rates are represented by these residuals, which successfully isolate differences that cannot be accounted for by seasonal, global, or systematic factors. Stated differently, they represent distinct, national variations from the general market pattern. By applying this method, the analysis offers a more comprehensive knowledge of the dynamics of national premium growth, regardless of seasonal swings and broader market trends.

Undirected networks were constructed using partial correlation matrices based on the idiosyncratic residuals. Nodes represent countries, while edges indicate significant correlations between residual growth rates. Key network metrics were calculated to assess network structure and connectivity, each providing insights into different aspects of network topology. When calculating these measures for the whole network instead of a single node, averages are taken to obtain overall structural characteristics. These metrics, widely used in network science (e.g. Newman, 2010; Barabási, 2016; Xu et al., 2022; Battiston et al., 2012), identify key countries, structural linkages, and network vulnerabilities, providing insights into systemic stability and market behaviour.

The **degree** (k_i) of a node is the total number of edges connected to it, representing the number of direct relationships a country has. Higher degree values indicate more central countries with extensive connections. The **weighted degree** extends the degree metric by accounting for edge weights, reflecting the strength of each connection by calculating the average sum of the weights of connections for each node as

$$WD_i = \sum_j w_{ij}$$

where w_{ij} represents the weight of the edge between nodes i and j . Countries with higher weighted degrees have stronger and more numerous relationships.

The **clustering coefficient** measures how closely connected a node's neighbours are, indicating the extent to which they form localized clusters. It is a measure of the likelihood of nodes connected to a node also being connected to each other. The local clustering coefficient for a node i is given by

$$C_i = \frac{2T_i}{k_i(k_i - 1)}$$

where T_i represents the number of triangles (fully connected triplets) involving node i , and k_i is its degree. High clustering suggests strong local group formation and tightly interconnected markets, i.e. the formation of strongly localized economic clusters (Newman, 2010).

Betweenness Centrality identifies nodes that frequently act as bridges between other countries by lying on their shortest paths. It is calculated as

$$BC_i = \sum_{s \neq i \neq t} \frac{\sigma_{st}(i)}{\sigma_{st}}$$

where σ_{st} represents the total number of shortest paths between nodes s and t , and $\sigma_{st}(i)$ is the number of those paths passing through node i . Higher values indicate countries that play a critical role in connecting otherwise isolated parts of the network. The overall network's betweenness centrality, like other node-level measures, can be analysed at the network level using the average betweenness centrality across all nodes (Barabási, 2016).

The **assortativity degree** (coefficient) measures the tendency of nodes to connect to others with similar degrees. It is given by

$$r = \frac{\sum_{ij} (k_i k_j) - \left[\sum_{ij} \frac{k_i + k_j}{2} \right]^2}{\sum_{ij} (k_i^2 + k_j^2) - \left[\sum_{ij} \frac{k_i + k_j}{2} \right]^2}$$

where k_i and k_j are the degrees of connected nodes. Positive values indicate that highly connected nodes link to other highly connected nodes, while negative values suggest the opposite.

The **density** measures the proportion of observed edges relative to all possible edges in a network:

$$D = \frac{2E}{N(N-1)}$$

where E is the number of observed edges, and N is the number of nodes in the network. A denser network reflects higher overall connectivity between countries.

The **average path length** is the average shortest distance between any two nodes in the network. It is calculated as

$$L = \frac{1}{N(N-1)} \sum_{i \neq j} d(i, j)$$

where $d(i, j)$ represents the shortest path between nodes i and j . Shorter paths indicate higher efficiency in communication or flow within the network. On

the other hand, the **diameter** is the longest shortest path between any two nodes in the network. It reflects the overall reachability and scale of the network. These two metrics are calculated as global values that summarize the system's overall structural efficiency for the whole network.

Power-law exponent assesses the network's structural organization, where a lower exponent indicates reliance on a few central hubs to maintain connectivity. A network is said to follow a power-law degree distribution if the probability $p(k)$ of a node having k connections follows

$$P(k) \sim k^{-\gamma}$$

where γ is the power-law exponent, which determines the shape of the degree distribution.

Small world property describes networks where most nodes are not direct neighbours, but can be connected in a few steps, with a balance of strong local clustering and short global distances, ensuring efficient local and overall connectivity. In this study it is calculated as the ratio of the average path length and average clustering coefficient.

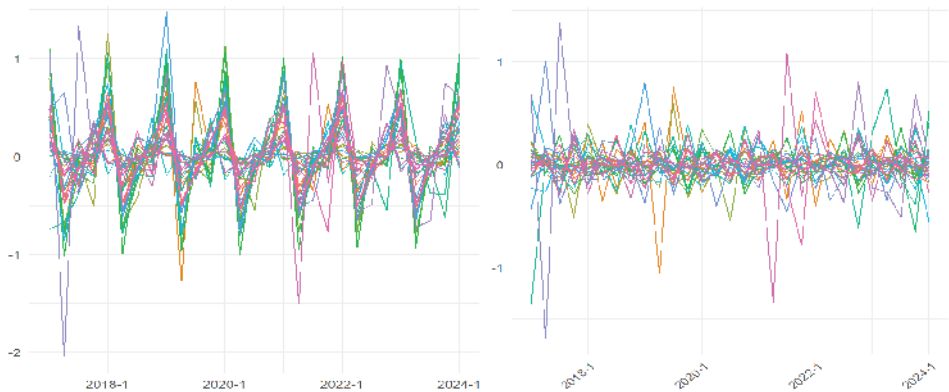
Networks were visualized with graph-based representations, where edges were weighted to reflect the strength of correlations and coloured to distinguish positive and negative relationships. Partial correlation matrices were analysed before and after market factor and country-specific adjustments to highlight the impact of these transformations. All analyses, from pre-processing to network construction, were conducted in R (R Core Team, 2024).

RESULTS

LOGARITHMIC PREMIUM GROWTH ACROSS COUNTRIES

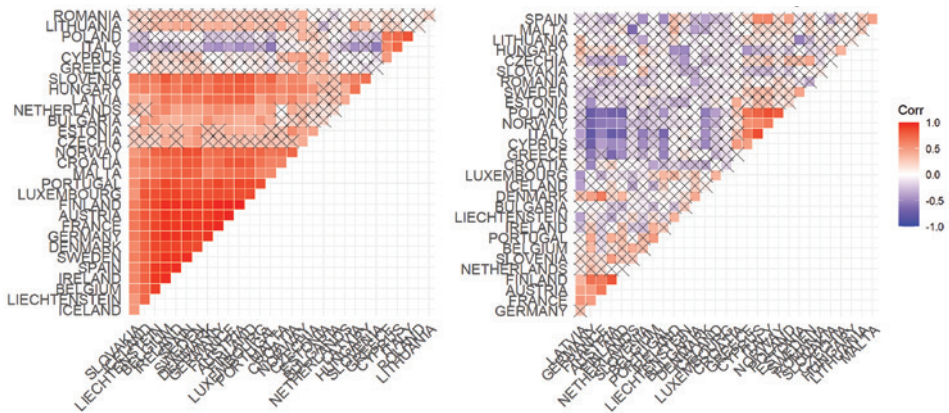
The log premium growth rates for non-life premiums are visualized in Figure 4, which consists of two panels. The left panel shows the original logarithmic premium growth rates for all countries over the analysed period. Countries are represented with different colours. The right panel shows the log premium growth rates after removing the overall market-wide growth trend (market factor) and country-specifics. This adjustment isolates the idiosyncratic growth rates, removing deviations from both global and local patterns.

Figure 4: Non-life growth rates across countries – original (on the left) vs. after factor removal (on the right)



In order to explore the interconnectedness of premium growth across countries, the pairwise correlations of logarithmic premium growth rates were calculated. The left panel of Figure 5 displays the correlation matrix derived from the original premium growth data for all countries. This visualization highlights the degree of synchronization in premium growth across countries, capturing both market-wide dynamics and regional similarities. The right panel of Figure 5 captures the residual correlations that are not explained by these broader influences by showing the correlations after factor removal.

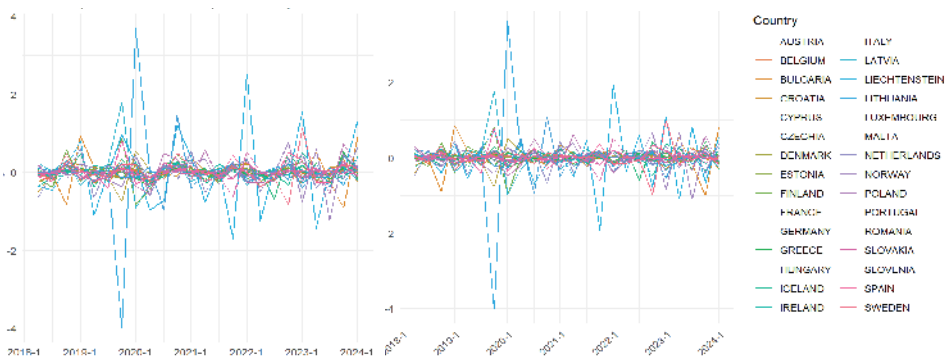
Figure 5: Non-life correlations – original (on the left) vs. after factor removal (on the right)



In the original correlation matrix, almost all countries exhibit high correlations. These patterns reflect how market-wide factors, such as global economic conditions, influence premium growth alongside country-specific characteristics. The correlation matrix after factor removal reveals a more nuanced view of the relationships between countries, since any remaining correlations are likely driven by deeper structural similarities such as shared exposure to specific risks or coordinated policy responses. For instance, Germany and Austria continue to exhibit significant correlation, suggesting structural linkages, while the previously strong correlation of Slovakia and Iceland diminishes, indicating that they were largely influenced by broader market trends.

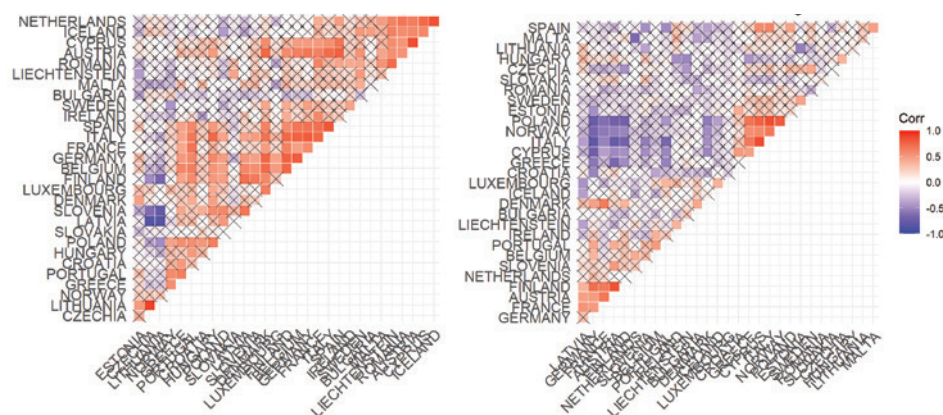
The log premium growth rates for life insurance premiums are visualized in Figure 6. The left panel shows the original logarithmic premium growth rates for all countries over the analysed period. The right panel again shows the log premium growth rates after removing the overall market-wide growth trend (market factor) and country-specific components.

Figure 6: Life growth rates across countries – original (on the left) vs. after factor removal (on the right)



The pairwise correlations of logarithmic premium growth rates for life insurance are given in Figure 7. The left panel of Figure 7 displays the correlation matrix derived from the original premium growth data for all countries. The right panel of Figure 7 shows the residual correlations after removing both market-wide and country-specific components.

Figure 7: Life correlations – original (on the left) vs. after factor removal (on the right)



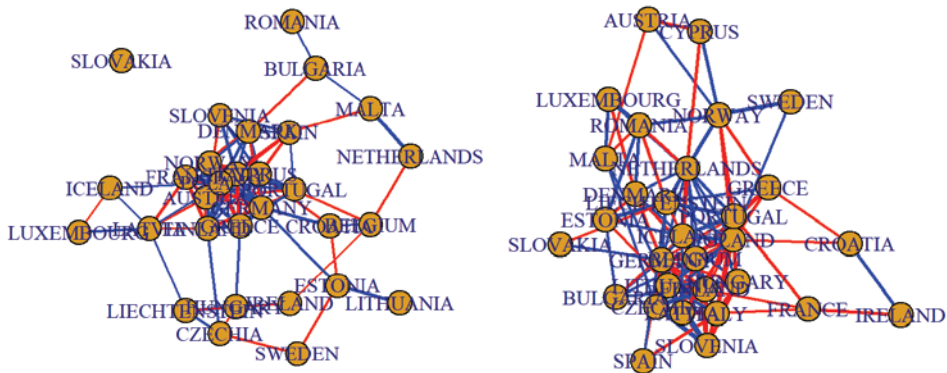
In life insurance, correlations between countries are lower than in non-life insurance in the original data, but still notable. This suggests that life insurance markets are influenced by structural factors and long-term trends rather than short-term events or seasonality. After removing market-wide and country-specific components, life insurance correlations further decrease, but the reduction is less pronounced compared to non-life insurance. This persistence of correlations indicates that the relationships in life insurance are not solely driven by global or local effects, but reflect deeper, structural linkages between countries.

The results highlight the key differences in correlation behaviour between life and non-life insurance. Non-life insurance shows initially strong correlations driven by seasonal patterns and short-term shocks, but these correlations weaken significantly after removing global and local effects. In contrast, life insurance correlations are initially lower, decrease moderately after factor removal, and remain more stable. This reflects the influence of long-term structural drivers in life insurance markets, which are less sensitive to short-term factors but more interconnected overall. This combined approach underscores the importance of separating market-wide effects from idiosyncratic and structural factors. It offers a deeper understanding of the interplay between shared risks, market conditions and country-specific dynamics.

NETWORK ANALYSIS OF PREMIUM GROWTH AFTER FACTOR REMOVAL

In order to further explore the interconnectedness of premium growth, the analysis involved a construction of networks for non-life and life insurance premiums after removing the market-wide and country-specific factors. These networks illustrate the relationships between countries based on the residual premium growth rates, where stronger connections indicate significant pairwise correlations that remain after adjustments. The networks for non-life and life insurance premiums presented in Figure 8 reveal clear structural differences between the two insurance sectors. In this context, the Fruchterman-Reingold layout technique (Fruchterman & Reingold, 1991), a force-directed approach that arranges nodes according to a simulated physical system, is used to depict networks in this investigation. As a result, the network's general structure is revealed through a visually intuitive depiction where strongly connected nodes cluster together. Instead of emphasizing specific entities, the main goal of this visualization is to shed light on the network's topology, including its form, clustering patterns, and general connection. Because the layout emphasizes structural clarity above individual node separation, not all things are clearly visible. This design decision facilitates the comprehension of more general connectivity patterns, including community formations, key hubs, and hierarchical interactions within the network.

Figure 8: Partial correlation networks – non-life (on the left) vs. life insurance (on the right)



The non-life insurance network seems to be characterized by a more fragmented structure, with fewer connections between countries and notable hubs of strong relationships. In contrast, the life insurance network appears more

cohesive, with more evenly distributed connections across countries. The stronger connectivity reflects the persistence of shared long-term structural drivers, such as demographic trends, regulatory frameworks, and financial market integration, which remain influential even after factor removal. In order to provide clear insights into the differences in connectivity, clustering and structural characteristics of the two networks, the key metrics for each network are presented in Table 3.

Table 3: Key network metrics for non-life and life insurance

Metric	Non-Life	Life
Degree (Average)	5.867	7.333
Weighted Degree (Average)	3.102	4.186
Clustering Coefficient (Average)	0.449	0.533
Betweenness Centrality (Average)	18.9	13.9
Assortativity (Average)	0.442	0.086
Density	0.202	0.267
Average Path Length	1.096	0.960
Diameter	2.388	2.030
Power-Law Alpha	4.007	8.225
Small-world property	2.441	1.801

The life insurance network exhibits higher average degree (7.333 vs. 5.867) and density (0.267 vs. 0.202), indicating a more cohesive structure with stronger overall connectivity across countries. This reflects the global nature of life insurance, driven by shared structural factors such as demographics and financial market integration. The non-life insurance network, with fewer connections and lower density, highlights a more fragmented structure, often dependent on regional hubs.

The higher clustering coefficient in life insurance (0.533 vs. 0.449) suggests tighter-knit clusters of interconnected countries. These clusters may represent regions with similar regulatory frameworks or demographic patterns. The lower clustering of non-life insurance reflects its reliance on specific hubs and the more dispersed nature of event-driven risks.

The higher assortativity in non-life insurance suggests a more homophilic structure, where markets with similar characteristics cluster together. This could highlight regional or sectoral trends driving non-life insurance. The near-zero assortativity in life insurance suggests a more heterogeneous structure, where different market dynamics are at play, potentially driven by a mix of high-degree and low-degree interactions.

Life insurance has a shorter average path length (0.960 vs. 1.096) and a smaller diameter (2.030 vs. 2.388), indicating a more efficient network structure where countries are more closely linked. Non-life insurance exhibits a stronger hierarchical structure, as shown by its lower power-law alpha (4.007 vs. 8.225) and higher small-world property (2.441 vs. 1.801). This reflects a reliance on key hubs to maintain network cohesion, increasing vulnerability to disruptions affecting these central nodes.

In order to further distinguish the roles of individual countries, the top three performers for each metric in the non-life and life insurance networks are extracted. These results are summarized in Table 4 for non-life and in Table 5 for life insurance.

Table 4: Top countries for non-life network metrics

Metric	1st Place	2nd Place	3rd Place
Degree	Cyprus (13)	Italy (13)	Germany (12)
Weighted Degree	Italy (8.43)	Poland (7.61)	Cyprus (7.21)
Clustering Coefficient	Luxembourg (1.00)	Norway (0.89)	Slovenia (0.83)
Betweenness Centrality	Denmark (54)	Latvia (51)	Germany (50)

Table 5: Top countries for life network metrics

Metric	1st Place	2nd Place	3rd Place
Degree	Poland (17)	Germany (15)	Belgium (14)
Weighted Degree	Poland (8.60)	Germany (7.75)	Belgium (7.74)
Clustering Coefficient	Slovakia (1.00)	Sweden (1.00)	Slovenia (0.86)
Betweenness Centrality	Poland (76)	Germany (46)	Netherlands (38)

In terms of non-life insurance, Cyprus, Italy and Germany appear as significant actors, demonstrating their importance as key hubs in the fragmented network. Cyprus's high level of centrality, for example, may stem from its status as an EU insurance passporting hub, enabling simple licensing that encourages corporations from Europe and the United States to build operations and monitor MENA activities. Italy's high weighted degree (8.43) emphasizes its strong and substantial correlations, which represent both the number of connections and their strength. In contrast, Germany's betweenness centrality (50) emphasizes its function as an important intermediary. Poland leads in life insurance across all parameters, probably due to Central and Eastern Europe's economic convergence with Western Europe. Germany routinely ranks second, demonstrating its strategic relevance in preserving network cohesiveness.

Countries with perfect clustering coefficients (1.00), such as Slovakia in life insurance and Luxembourg in non-life insurance, show close-knit local ties. These clusters can be an indication of shared risk exposure or regional regulatory harmonization.

CONCLUSION

A thorough examination of the interconnection and structural aspects of life and non-life insurance networks after removing market-wide and country-specific elements was conducted as part of this study. The findings show considerable disparities in network dynamics, emphasizing the fragmented and hierarchical nature of non-life insurance against the cohesive, globally connected structure of life insurance. The approach adds to our understanding of how insurance markets interact and how their structure effects resilience, collaboration, and systemic risks. Because of its emphasis on regional hubs, non-life insurance is well-suited to localized, personalized products such as catastrophe risk insurance or vehicle insurance, which meet specific regional risks and demands. Life insurance, on the other hand, is more resilient due to its integrated network, with key countries providing stability. This structure facilitates international cooperation and the creation of cross-border products.

Systemic risk factors are also highlighted in the study. The analysis gives insurers and policymakers practical insights to improve network resilience by identifying the important nodes and clusters. Germany's prominence in both networks, for instance, highlights its function in preserving unity, and keeping an eye on non-life insurance hotspots like Cyprus is essential for controlling regional threats.

Nevertheless, the analysis does have its limitations. The static character of the analysis does not take into consideration the temporal dynamics. Temporal network analysis may be used in future studies to better understand these dynamics and offer useful insights into how networks change over time. Furthermore, relying just on pairwise correlations may miss causative links or overstate interdependencies. These issues could be resolved by integrating external variables such as macroeconomic indicators, GDP or population, or by employing causal network models. Notwithstanding these drawbacks, the study shows how useful network analysis is for comprehending the dynamic and structural features of insurance markets. The investigation lays the groundwork for insurers and governments looking to maximize the stability and effectiveness of insurance networks by identifying disparities in connectedness and cohesion between life and non-life insurance networks.

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