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MONOTHEMATIC ISSUE 2026
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Sustainable cities

This monothematic issue seeks to create a platform for interdisciplinary research on sustainable cities. Urban areas have become central to the global economy, yet they also face significant social and environmental challenges. Without addressing these issues, cities risk becoming overcrowded, polluted, and increasingly detrimental to the quality of life for their inhabitants. We invite submissions of original papers from diverse academic disciplines, presenting innovative research that can contribute to overcoming the key sustainability challenges facing urban areas worldwide.

Guest editors

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Important dates

Submission open date: June 1, 2025
Manuscript submission deadline: October 31, 2025
The submisison of the articles is accepted through the journal's editorial system:
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Publishing of articles: September 2026

Background and objectives

Sustainable cities face persistent challenges despite the Sustainable Development Goals (SDGs) introduced under the UN 2030 Agenda and later integrated into EU policies. Although these goals have been recognized for nearly 10 years, cities continue to struggle with their practical implementation.

Key obstacles include theoretical, technological, and practical gaps in urban sustainability. A major issue is the weak connection between sustainable and smart cities. Many initiatives focus primarily on infrastructure such as energy, transport, and waste, without fully integrating broader urban systems where smart technologies could enhance sustainability. To address these gaps, cities

need innovative approaches, including big data analytics, urban simulation models, and ICT-driven solutions, to improve decision-making and resource efficiency. Additionally, the lack of a standardized framework for evaluating sustainable city models makes it difficult to establish best practices and scalable solutions (Bibri & Krogstie, 2017).

To overcome these challenges, cities should focus on two key areas: i) sustainable urban planning; and ii) public participation & citizen science.

i) Sustainable urban planning. Sustainable urban planning is the process of designing, developing, and managing cities to meet present needs without compromising the ability of future generations to meet their own. It integrates environmental, social, and economic considerations to create livable, resilient, and resource-efficient urban environments (Jabareen et al., 2006; UN-Habitat, 2020).

Several key aspects define sustainable urban planning:

- Environmental sustainability focuses on reducing pollution, conserving resources, and enhancing green spaces to minimize ecological impact (UN-Habitat, 2020).
- Social equity ensures inclusive urban development by providing affordable housing, accessible public services, and equal opportunities for all citizens (European Commission, 2016).
- Economic viability supports sustainable industries, job creation, and the development of smart infrastructure to foster long-term growth (Jabareen, 2006).
- Smart urban solutions integrate ICT, big data, and innovative transport systems to enhance efficiency and connectivity (Batty et al., 2012).
- Resilience and adaptation are crucial for designing cities capable of withstanding climate change and natural disasters, ensuring long-term urban sustainability (IPCC, 2014).

ii) Public participation and citizen science. Public participation and citizen science play a crucial role in sustainable urban development. Engaging citizens in urban planning ensures that diverse perspectives are considered, leading to policies and projects that reflect the actual needs of the community (UN-Habitat, 2020).

Citizen science, where residents actively collect and analyze data, enhances urban sustainability by providing real-time insights into environmental issues such as air quality, waste management, and biodiversity (Haklay et al., 2018). Additionally, digital platforms and smart city technologies empower communities by enabling participatory governance and collaborative problem-solving (European Commission, 2020). By integrating public engagement and citizen-driven data, cities can become more resilient, adaptable, and people-centered, ensuring long-term sustainability (Irwin, 2018).

The role of universities and European University Alliances in sustainable cities

A special focus in this monothematic issue is the role of universities and the European Alliance of Universities in promoting sustainable cities. Universities play a vital role in advancing urban sustainability through research, innovation, and education. Additionally, they shape urban environments that support inclusivity, creativity, and sustainability (Heijer & Curvelo Magdaniel, 2012).

University campuses themselves have the potential to contribute to sustainability through various initiatives. For example, open university campuses, built on the principle of blurring campus boundaries, can support citizen engagement, reduce the environmental impact of universities, and improve urban mobility and citizen well-being (Barratt & Swetnam, 2022).

The latest European initiatives focus on building European University Alliances, which have a significant impact on urban sustainability. By fostering interdisciplinary research, strengthening education networks, and creating new partnerships with local governments and industries, these alliances contribute to climate adaptation, circular economy strategies, and smart urban infrastructure.

Objectives of the monothematic issue

The primary objective of this monothematic issue is to expand the discussion on current challenges in sustainable city development and explore tools and approaches that can help overcome these obstacles. By examining sustainable urban planning, public participation, and the role of universities, this issue aims to contribute to the advancement of innovative, scalable, and inclusive solutions for the sustainable cities of the future.

Aim of the monothematic issue and topics

This monothematic issue explores various aspects of sustainable cities. We invite contributions from researchers across different disciplines who can provide research findings, innovative approaches, case studies, or reviews on supporting sustainable development in urban areas.

We welcome papers addressing, but not limited to, the following topics:

- **Sustainable cities and communities** (sustainable housing; public transport and mobility).
- **Enhancing city resilience to climate change and disasters** (innovation and infrastructure; resilient and sustainable urban infrastructure).
- **Innovation and entrepreneurship ecosystems.**
- **The role of universities in sustainable cities** (The European University Alliance's contribution to sustainable cities; university campuses as integral parts of sustainable cities).
- **Sustainable urban planning.**
- **Culture, well-being, social inclusion, and public participation in sustainable cities.**
- **Sustainable policy and governance.**
- **Smart mobility and smart logistics.**
- **Energy transition in urban environment**

We encourage interdisciplinary perspectives and practical insights that contribute to the advancement of sustainable urban development.

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Regional income convergence in Central Europe: Evidence from a pair-wise approach

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Abstract: *Regional disparities are usually monitored in terms of economic performance. But as pointed out by many scholars, research has to look beyond GDP, investments, unemployment, and focus also on regional inequality in measures of well-being, for example, the disposable income of households. Therefore, this article examines the income disparities among the regions of Central European countries. We apply the probabilistic definition of convergence that is tested by the time series cointegration analysis. However, in our analysis, convergence criteria are tightened to increase robustness. In particular, we propose to require meeting of both criteria, i.e., stationary and absence of unit root, instead of one for the acceptance of the cointegration condition of regional convergence. Empirical analysis shows that despite the application of stricter conditions, the hypothesis of income convergence between Central European regions in 2003–2022 cannot be rejected. In particular, we found inner-country convergence in most countries. However, the involvement of individual regions in cross-country convergence varies widely. The results suggest that convergence intensity in the easternmost and westernmost regions is weak. However, we identified a "belt of convergence" along the border of the former Iron Curtain. These findings support the hypothesis of club convergence suggested by some scholars in the region of Central and Eastern Europe. On the other hand, our results significantly challenge previous research that claimed Central European transition economies are converging, especially towards German regions. Instead, our results indicate that convergence towards German regions is weak, while convergence towards Austrian regions is much more pronounced. Finally, uncovering how regions are converging at different rates and towards different steady-states can help to optimize the allocation of EU funding.*

Keywords: *Income disparity, Central Europe, cointegration analysis, regional convergence.*

JEL Classification: *R11, D31.*

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Introduction

The examination of inequality and redistribution constitutes a pivotal discourse within the realm of regional science and policy. Mainstream research focuses on regional differences in economic performance, such as growth, investments, and employment or unemployment (Capello & Nijkamp, 2019). For many years, however, scholars have pointed out that research has to look beyond economic performance and focus on regional inequality in measures of well-being (Doyle & Stiglitz, 2014). In fact, the measure of interest for people is not GDP, but wages, salaries, taxes and subsidies, or from an economic point of view, the net disposable income of households (income; Faggian et al., 2023). There are three main reasons for this. Firstly, disposable income

is a household measure and therefore relates to the place of residence and living conditions of inhabitants (Corvers & Mayhew, 2021). Secondly, disparities in income have a detrimental effect on well-being (Nettle & Dickins, 2022). Third, income inequalities have an impact on regional economic growth, potential, and environmental aspects. (Fuka et al., 2023; Topuz, 2022).

Hajdu and Hajdu (2015) found that people in less developed Eastern European countries are more negatively affected by income inequality than people in more developed Western Europe. Therefore, the expectation of an economic boom and additional financial support that boosts income growth in regions was stimuli for eastern countries to join the European Union (EU) in 2004 (Cieslik & Turgut, 2021). In addition, the expansion of the EU towards the east in 2004 heightened the demand for a more advanced regional policy. As regional policy became more significant, there was a growing need to develop methods for assessing regional disparity, which can help validate the expenditure of funds from both the EU budget and national resources (Zdrazil & Kraftova, 2023).

Central Europe presents a significant opportunity for in-depth analysis of income disparities across regions. While there is extensive research on income disparity in general, a number of studies on the regions of Central Europe is limited (Dorjnyambuu, 2024; Kapidzic et al., 2022). Spruk (2013) argues that this is due to specificity of transition countries that provide relatively short period when convergence hypothesis could be examined. Central Europe includes both traditional (EU15) countries with rather more developed regions (Austria and Germany) and transition countries, which joined the EU in 2004 (Czechia, Hungary, Poland, Slovakia, and Slovenia). The latter countries are regarded as less developed and, therefore, eligible to gain more European funds to promote cohesion.

Following the above, the research aim of this paper is to assess the income disparities between the regions of the Central European countries. We apply the less frequently used probabilistic definition of convergence (Pesaran, 2007; Pesaran et al., 2009), which is based on a pair-wise approach to measure regional convergence in terms of the limit of expected income gaps. A high relevance of this measurement was, however, confirmed by a number of empirical studies (Arvanitopoulos et al., 2021; Drager et al., 2023; Duro et al., 2023; Ngamaba et al., 2018). As pointed by Johnson and Papageorgiou (2020) and Shibamoto et al. (2016), this kind of cointegration approach to testing the hypothesis of convergence can be described as the most comprehensive modern method with a highly informative value of its results.

1. Theoretical background

At the end of the 20th century, the assumption of a general tendency toward the convergence of national or regional economies was significantly challenged by new models based on endogenous growth factors (Barro & Sala-i-Martin, 2004; Mankiw et al., 1992). However, the new approach does not clearly state whether convergence or divergence should be a general tendency of regional development (Martin, 2001). This ambiguity of the model in a fundamental issue of disparities development led to the need of a more sophisticated analytical apparatus to measure the extent and development of spatial inequality. Johnson and Papageorgiou (2020) provide a comprehensive discussion of different concepts by which convergence can be understood, as well as methodologies that may be employed for measurement.

The new look also supposes the creation of regional disparity in economic performance, household income, employment, and education attained. In particular, the importance of inequalities in income has been pointed out (Atkinson, 2017). The empirical research concludes a negative association between income inequality and accumulation of both assets (Blanchet & Martinez-Toledano, 2023) and human capital (Mdingi & Ho, 2021), confidence in society and institutions (Rozer & Kraaykamp, 2013), social mobility (Polacko, 2021), and happiness and well-being of a population (Chen & Hsu, 2024). Conversely, income inequality demonstrates a positive correlation with crime (Itskovich & Factor, 2023), pollution (Fuka & Bata, 2024), envy (Hajdu & Hajdu, 2015), and productivity (Kanbur & Stiglitz, 2016). Finally, the real data show that decreasing of income inequality is not as often as decreasing of inequality in GDP (Ben-David & Kimhi, 2004).

Taking into account the limited number of studies that have addressed regional disparities in Central Europe, the results on

the processes of convergence or divergence in income are mixed. Based on the simple approach of beta-convergence, Crespo Cuaresma et al. (2016) found that income disparities are declining and expect this process to continue. Alcidi (2019) came to the same conclusion, however, with the question of whether the convergence process will continue. Nagy and Siljak (2022) identified income convergence between the new and old EU member states while emphasizing that notable variations exist among the new member states. Markowska et al. (2022) and Monfort (2020) developed similar conclusions, noting the different speeds of convergence. However, Cieslik and Wcislik (2020) disagree with any convergence patterns and argue that eastern regions are converging only towards France and Germany. Based on both beta- and sigma-convergence processes, Spruk (2013) confirmed the existence of catching-up processes in income. Rapacki and Prochniak (2019) argue that this is the effect of EU membership. Holobiuc (2020) agrees with this conclusion, but points out that the benefits of convergence were not equally distributed. Conversely, Borsi and Metiu (2015) argue that there is no clear evidence of real income convergence in the enlarged EU.

However, there are a number of studies that argue that the conclusions about disparities in Central Europe are very ambiguous. Matkowski et al. (2016) revealed that the convergence process is not continuous; in particular, the most intensive convergence appeared just before and after the EU enlargement in 2004. Cieslik and Turgut (2021) claim that the breakthrough comes after the new countries were admitted to the Schengen area in 2007. In contrast, numerous studies (e.g., Licchetta & Mattozzi, 2023; Nagy & Siljak, 2022) noted signs of divergence, particularly following the 2008 crisis, while the impact of EU enlargement and integration on income disparities appears to be questionable, whereas the effects on income disparities of EU enlargement and integration are spurious. Based on more comprehensive cointegration approaches, Gligoric (2014) found that convergence processes in income prevail, but these processes are not present at the whole sample, and they are not well obvious. Similar results indicating the club convergence in income have also been accessed by Monfort et al. (2013) and Duro et al. (2023). In addition, Holubiuc (2020) argues that capital cities are the winners of the convergence process in Central and Eastern Europe.

Artelaris et al. (2010) offer a different perspective when they argue that periods of convergence in regional income alternate with periods of divergence; hence, it is not easy to develop general conclusions about income disparities in Central European countries. Dogan and Saracoglu (2007) used 5 different panel root tests to investigate disparities in income, but did not confirm the income convergence hypothesis. Furthermore, many scholars conclude that regional convergence in income is more common across Central European countries, while inner-country disparities are on the rise (Kokocinska & Puziak, 2018; Zdrazil & Applova, 2016). The explanations for this are variegated; e.g., Kuttor (2009) addressed the main reasons for the polarisation of economics, especially the growth of capital city regions, and geographical advantage of western regions that are closer to the more developed markets in EU15 countries. However, Duarte et al. (2022) assume the position in global value chains also matters.

2. Research methodology

To fulfil the research aim, the cointegration approach will be used to analyze the development of disparities for this study. It should be noted that this approach to testing convergence is fundamentally different from the conventional definition of convergence established by, e.g., Baumol (1986), Barro and Sala-i-Martin (2004), and Mankiw et al. (1992). The conventional approach defines convergence based on an inverse relationship between levels of income and growth (Barro, 1991), thereby indirectly deducing long-term processes in development on the basis of relations in the sample. However, the cointegration approach lies in the assessment of a time series, allowing for the direct testing of convergence hypothesis in terms of a dynamic-stochastic environment (Bernard & Durlauf, 1995; Pesaran, 2007). In fact, the cointegration approach to testing convergence is a very comprehensive modern method with a highly informative value of its results (Johnson & Papageorgiou, 2020; Shibamoto et al., 2016).

2.1 Cointegration approach to regional convergence

We follow the approach of cross-country (regional) convergence in terms of the limit

of expected income gaps (Bernard & Durlauf, 1995; Pesaran, 2007; Pesaran et al., 2009). It applies a stochastic definition to processes of economic fluctuation and convergence, and uses an econometric approach for the assessment of the development of disparities based on testing for the presence of a unit root and cointegration of time series (Arvanitopoulos et al., 2021). In their pioneering work, Bernard and Durlauf (1995) define convergence for a pair of regions as Equation (1):

$$\lim_{s\to\infty} E\left(y_{i,t+s} - y_{j,t+s} \middle| I_t\right) = 0 \tag{1}$$

where: y – log per capita income of a region; I_t – information set in time t, which contains previous and current income $y_{i,t-s}$ (for i = 1, 2, …, n at all horizons s = 0, 1, …).

This definition implies that a necessary but not sufficient condition for the convergence of regions i and j is cointegration of their income with cointegrating vector [1; −1]. However, such a condition for acceptance of convergence is very strict in assessing real data. In particular, this would indicate convergence only for economies with very similar parameters, including their long-run steady-state (Le Pen, 2011). Following the limitation but keeping the advantages of the cointegration approach to testing regional disparity, Pesaran (2007) and Pesaran et al. (2009) propose an application of the so-called probabilistic definition of convergence, see Equation (2). This definition is based on the conditional probability of the occurrence of each pair-wise income gap outside a predefined interval, i.e., that the absolute value of income gap ($y_{i,t+s} - y_{j,t+s}$) being larger than some positive constant C. Based on this approach, a pair of regions can then be classified as converging if for positive constant C a tolerance probability measure $\pi \geq 0$.

$$\Pr\left\{\left|y_{i,t+s} - y_{j,t+s}\right| < C | I_t\right\} > \pi \tag{2}$$

As is evident, Pesaran's modification does not lie in the partial evaluation of an individual time series, which was an initial stage of the Bernard-Durlauf approach. The probabilistic convergence approach lies in the analysis of the residuals of the time series expressed by their difference ($y_{i,t+s} - y_{j,t+s}$), i = 1, 2, …, n − 1, and $j = i + 1, 2, \ldots, n$. Therefore, it is always necessary to perform an individual test for each pair of regions in the sample.

Based on the results of individual tests between each pair of regions, the probabilistic approach is then based on the assessment of the ratio ($\bar{Z}_{n,t}$) between the number of pair-wise income gaps that meet the established criteria of convergence ($Z_{ij,t}$ = 1) and all sorts of pair-wise income gaps, whereas this ratio can be easily expressed by Equation (3). When applying this extension, Pesaran (2007) showed that during the application of tests with null of divergence (unit roots tests) and null of convergence (stationary tests), a low ratio ($\bar{Z}_{n,t}$) getting closer to the size of the test α, as n and $t \to \infty$, see Equation (4), can be expected in case of divergence. And vice versa, convergence can be spoken of, if $(\bar{Z}_{n,t}) > \alpha$, whereas it is getting closer to the unity, as n and $t \to \infty$, see Equation (5). These connections can be interpreted as: the higher the ratio ($\bar{Z}_{n,t}$), the more valid is the convergence process (Le Pen, 2011).

$$\bar{Z}_{n,t} = \frac{2}{n(n-1)} \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} Z_{ij,t} \tag{3}$$

$$\lim_{t\to\infty} E\left(\bar{Z}_{n,t} \middle| H_0\right) = \alpha \tag{4}$$

$$\lim_{t\to\infty} E\left(\bar{Z}_{n,t} \middle| H_0\right) = 1 \tag{5}$$

The increased computational complexity caused by individual testing of each pair of regions, i.e., [$n(n-1)/2$] tests for the sample of n regions, is outweighed by the major advantages of this approach. In particular, the literature argues maintaining of a high level of information connected with high robustness of the method, namely:

i) It does not require the involvement of a benchmark entity. Therefore, the results are not compromised by choosing the wrong benchmark (Holmes et al., 2011; Le Pen, 2011).

ii) It allows testing the hypothesis for convergence/divergence in a short time series where n is great against t (Pesaran, 2007). Compared with traditional panel methods, this is a great advantage because the assessment is robust to cross-section dependence and aggregation (Pesaran et al., 2009).

iii) It overcomes the problems associated with technological progress, as it acknowledges its development both in the form of a deterministic and stochastic process, regardless of whether

it contains the component which could be described as random walk or not (Pesaran, 2007).

2.2 Specification of a pair-wise approach

We apply Pesaran's approach to testing convergence. A high relevance of this measurement was confirmed by a number of empirical studies (Arvanitopoulos et al., 2021; Drager et al. 2023; Duro et al., 2023; Gligoric, 2014; Holmes et al., 2011; Le Pen, 2011; Shibamoto et al., 2016). The method is complex; therefore, we will now explain the specification of all procedures in brief.

The convergence criterion of region pairs is considered the stationarity of residual (i.e., gap) series compiled of differences in the time series of these regions, or better to say, a lack of deterministic and stochastic trends in gap series. This weakens the condition of equivalence of economies significantly; however, a predicative value of test conclusions of the convergence hypothesis is not reduced (Pesaran, 2007). In fact, this concept allows the result of the income gap series to be level stationary, which is a situation where the development process will not significantly deviate from the mean, but this mean may not be 0 (Pesaran, 2007; Pesaran et al., 2009). Also, the existence of more significant differences in the structural parameters of regional economies is allowed, but only if the regions have common stochastic and deterministic trends in the development of income. The requirement for a common stochastic trend can then be described as a cointegration condition and the requirement for a common deterministic trend as a cotrending condition (Le Pen, 2011). We applied three independent tests to examine both conditions. Cross-verification, however, allows strong conclusions to be considered about the development of regional disparities.

The testing of the convergence hypothesis of household disposable income across regions starts with the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) test (Kwiatkowski, 1992). This test works with the null hypothesis: *The series is stationary around a deterministic trend (i.e., estimated convergence)*; against the alternative hypothesis: *The series has a unit root (i.e., estimated divergence)*.

Although not rejecting the null of the KPSS test, convergence can be preliminarily estimated; our intention is to use the KPSS test as a complement to enhance the robustness of the results by subsequent application of a unit root test. Therefore, the estimation of convergence is required by both tests, i.e., with null of convergence (KPSS) and with null of divergence (generalized least squares Dickey-Fuller *t*-test; DF-GLS), for accepting the condition of convergence.

In this cross-check validation, we deviate from the usual procedure of testing convergence. In fact, previous studies (Arvanitopoulos et al., 2021; Holmes et al., 2011; Le Pen, 2011; Pesaran, 2007; Pesaran et al., 2009) usually present the application of KPSS and unit root tests as alternatives. However, they do not require reciprocal confirmation for the acceptance of the convergence condition. With our requirement for cross-check validation, we are actually able to filter out the series for which the stationary test or unit root test can fail independently. The application of both approaches thus serves as a confirmation of results and increases the robustness of testing (Kwiatkowski et al., 1992).

In the next step, we apply the unit root tests based on the Dickey-Fuller approach. In particular, we applied the generalized least squares Dickey-Fuller *t*-test (DF-GLS) defined by Elliott et al. (1996). The DF-GLS modification consists of a series transformation using generalized least squares before the application of the Dickey-Fuller *t*-test. When applying the test in accordance with Pesaran (2007), a model with an intercept and a linear deterministic trend is applied. The convergence criterion is a rejection of the null: *The series has a unit root (i.e., estimated divergence)*. In particular, rejection of null means acceptance of the alternative hypothesis: *The series has no unit root (i.e., estimated convergence)*. The DF-GLS test has substantially higher power compared to other Dickey-Fuller tests, especially when the series can be considered stationary (Zivot & Wang, 2006). In our case, this is supported by a selection of series on the basis of the application of the KPSS test.

Stationary and the absence of unit root in a series is a necessary but not sufficient condition for convergence. The approaches based on the Dickey-Fuller *t*-test may fail with respect to the issue of the identification of the deterministic trend, especially when the test data contain stochastic trend, which was clearly demonstrated by Gomez-Zaldivar and Ventosa-Santaularia (2011). Following Le Pen (2011),

the significance of the deterministic trend, which expresses a catching-up process in converging regions, is examined using a *t*-test with the null hypothesis: *There is no significant deterministic trend in a series*. However, rejection of null means acceptance of an alternative hypothesis: *There is a significant deterministic trend in a series (i.e., cotrending condition of convergence)*. Also, this is applied to the income gap series.

2.3 Data

The above methods are applied to data from the Eurostat Regional Statistics database (Eurostat, 2024). Annual data of disposable household income (in purchasing power standard, per inhabitant) are analysed. The analysis covers the 20-year series between 2003 and 2022. Considering the principles of topography, cultural and political criteria, we follow the common definition of Central Europe listed, e.g., in Encyclopaedia Britannica (2024). The reference level of research is NUTS 2 level of regions, that is, the level where the main activities of EU regional policy are carried out. Therefore, the research sample consists of: Austria (9 regions), Czechia (8), Germany (38), Hungary (8), Poland (17), Slovenia (2), and Slovakia (4).

We are aware that the sample comprises diverse economies and regions differing in their size, levels of development, and sectoral structure. Nevertheless, these countries not only share a geographic position in Central Europe but also an intertwined history and substantial economic connections. This is true even for Germany, to which many of the countries under study are linked and which played a key role in their transformation. In addition, Germany is seen as the engine of the region, contributing to the growth and development of the examined countries (Andor, 2019; Polster, 2021). From this viewpoint, this results in similarities regarding anticipated growth, income, and convergence trajectories (Corvers & Mayhew, 2021; Rauhut & Humer, 2020). A variety of recent empirical research has employed a similar sample of Central Europe, incorporating both small and large, as well as more and less developed, countries and regions (e.g., Bachtrogler-Unger et al., 2023; Cieslik & Wcislik, 2020; Holubiuc, 2020; Konya, 2023; Markowska, 2022)

Furthermore, Dorjnyambuu (2024) points out that studies concerning Central and Eastern Europe are largely concentrated on a select number of countries, partially because of their heterogeneity. Therefore, several (smaller) nations of Central Europe are not well-represented in the scholarly literature. Following that Dorjnyambuu (2024) calls for further research incorporating a wider range of samples of Central European countries and regions to ensure that the development of the field does not focus disproportionately on specific nations.

The sample of 86 regions required the examination of 3,655 series compiled from log per-capita income gaps within each step of the analysis (the analysis contains 3 steps). Therefore, only the summarising results of individual steps are presented and discussed in the following sections. The logarithmic transformation of the data for testing stationary is highly desirable due to the requirement of a normal distribution of data, which resulted from a linear form of the conducted test for stationary and unit root test, as well as for one sample *t*-test (Zar, 2010). In fact, this transformation suppresses undesirable trends in the data series (Wang, 2006). Given the breadth of analysis, it is not possible to present all of the results in this paper.

3. Results and discussion

As mentioned above, a KPSS test is applied to each pair-wise income gap series. This is followed by a DF-GLS test. Applying these tests, we can evaluate the cointegration condition. Starting with the KPSS test, we found 2,751 pairs of regions ($\overline{Z}_{i,j,t}$) are not rejecting the null of stationary. Since the sample size consists of 3,655 series, the ratio of estimated convergence in the sample of all regions ($\overline{Z}_{n,t}$) is 75.3%, which largely exceeds the level of significance (α = 5%). Based on this result, the first partial assumption for the acceptance of a common stochastic trend between pairs of regions has been met by a greater number of series than it would be possible to explain by an error rate of the test procedure.

These results are further detailed in Tab. 1, which shows information in the context of the relationships between regions within and across countries. However, the matrix depicts only a share of relations that meet the criterion of convergence ($\overline{Z}_{n,t}$). Here again, the regional convergence can be preliminarily assumed as a real process, since the percentage of no rejections of null exceeds the level of significance between the regions of all countries (except Slovakia and Slovenia). The regions of Slovakia do not show a relevant number

of common stochastic trends compared to regions of Germany and Poland. Slovenia does not show a common stochastic trend between its own regions. On this aspect, however, both small countries with few regions are disadvantaged by the methodology used.

However, within the cross-check validation of testing the common stochastic trend, the test for a unit root is also applied. In contrast, the null of the DF-GLS test refers to divergence. Therefore, the rejection of null can be interpreted as an indication of convergence. The results

Tab. 1: KPSS test summary – spatial view

	Austria	Czechia	Germany	Hungary	Poland	Slovakia	Slovenia
Austria	94.4*						
Czechia	84.7*	71.4*					
Germany	40.6*	54.6*	68.1*				
Hungary	98.6*	98.4*	95.1*	75.0*			
Poland	100.0*	99.3*	100.0*	100.0*	79.4*		
Slovakia	63.9*	46.9*	2.0	87.5*	4.4	100.0*	
Slovenia	44.4*	87.5*	100.0*	100.0*	100.0*	50.0*	0.0

Note: The values refer to % $(\overline{Z}_{n,t})$ of cases with no rejection of null; * estimated convergence (significant at 0.05 significance level).

Source: own

show that 606 pairs of regions $(\overline{Z}_{i,j,t})$ are rejecting the null of unit root; therefore, the ratio of estimated convergence in the sample of all regions $(\overline{Z}_{n,t})$ is 16.6%. Furthermore, the share of regions that met the estimated convergence (α = 5%) is significant, the number is much lower compared to the previous KPSS test. As shown in Tab. 2, the regions that most frequently fulfil the condition of convergence are located in Poland and Hungary. However, in accordance with the previous KPSS testing, divergence is estimated especially for Slovenian, Slovak and German regions.

At this point, it is important to note the fundamental difference between the frequencies of acceptance of the cointegration condition between the KPSS and DF-GLS tests. This is one of the reasons why we modify Pesaran's approach and

Tab. 2: DF-GLS test summary – spatial view

	Austria	Czechia	Germany	Hungary	Poland	Slovakia	Slovenia
Austria	38.9*						
Czechia	55.6*	35.7*					
Germany	0.6	3.3	21.3*				
Hungary	20.8*	40.6*	22.7*	35.7*			
Poland	35.3*	27.9*	9.1*	21.3*	29.4*		
Slovakia	0.0	3.1	2.6	0.0	0.0	16.7*	
Slovenia	0.0	0.0	0.0	6.3*	94.1*	0.0	100.0*

Note: The values refer to % $(\overline{Z}_{n,t})$ of cases with rejection of null; * estimated convergence (significant at 0.05 significance level).

Source: own

argue that requiring both conditions ensures a higher robustness of results, as pointed out by Kwiatkowski et al. (1992). At the same time, this modification reduced the possibility of a situation where individual tests may fail to identify a deterministic trend (Gomez-Zaldivar & Ventosa-Santaularia, 2011).

After proceeding with the evaluation of common stochastic trend (cointegration condition), an analysis of the existence of a common deterministic trend (cotrending condition) follows. This issue is examined via a *t*-test, which has a null of no deterministic trend. Therefore, the rejection of null refers to acceptance of the existence of trend (i.e., cotrending condition of convergence). The results show that 2,911 pairs of regions ($\overline{Z}_{i,j,t}$) are rejecting the null of no deterministic trend, therefore the cotrending condition is met by 79.6% of the regions ($\overline{Z}_{n,t}$), which largely exceeds the level of significance (α = 5%). However, the differences between countries are interesting. In many linkages, the trend indication is 100%, while in the others, it is only around 30%. In particular, Czechia and Slovenia achieve similar results in this regard, as presented in Tab. 3.

However, the individual tests per se track only individual aspects and do not tell us much about the evolution of regional income disparities. The strength of the cointegration approach lies in linking the results of all the tests (satisfying both conditions of cointegration

Tab. 3: ***T*-test summary – spatial view**

	Austria	Czechia	Germany	Hungary	Poland	Slovakia	Slovenia
Austria	61.1*						
Czechia	100.0*	28.6*					
Germany	30.7*	100.0*	74.3*				
Hungary	88.9*	32.8*	85.9*	57.1*			
Poland	100.0*	100.0*	100.0*	91.9*	69.1*		
Slovakia	61.1*	100.0*	55.3*	75.0*	100.0*	66.7*	
Slovenia	100.0*	46.9*	100.0*	25.0*	33.8*	100.0*	100.0*

Note: The values refer to % ($\overline{Z}_{n,t}$) of cases with rejection of null; * estimated convergence (significant at 0.05 significance level).

Source: own

and cotrending); only on this basis can we make inferences about regional convergence or divergence.

Therefore, the final step in testing the hypothesis of convergence is the connection and evaluation of the results of tests that have been applied to the income gaps of the series for each pair of regions. The results of the KPSS test, also those of DF-GLS, indicate the existence of convergence process. However, the number of pairs of regions that met the convergence (cointegration) condition is lower when applying DF-GLS. If we intersect these results, we found 588 (i.e., 15.3%) pairs of regions to have a common stochastic trend (cointegration condition). However, considering also the results of *t*-test (cotrending condition), the number of pairs decreases to 496. Since the sample size consists of 3,655 series, the ratio of estimated convergence by all tests in the sample of all regions ($\overline{Z}_{n,t}$) is 13.6%. These results are further detailed in Tab. 4 that shows the context of the relationships between regions within and across countries.

In summary, we can say that ($\overline{Z}_{n,t}$) exceeds the significance level (α = 5%), and therefore we can confirm the convergence process in terms of household disposable income in Central Europe. In fact, the number of regions showing convergence could not be explained by random influences or rather by an error term of the methods applied. However, at the same time, the measured values show that, despite the confirmation of convergence, it can also be conversely considered that the differences among a number of regions are not decreasing.

Tab. 4: Income convergence in Central Europe – spatial view, final summary

	Austria	Czechia	Germany	Hungary	Poland	Slovakia	Slovenia
Austria	33.3*						
Czechia	51.4*	14.3*					
Germany	0.6	3.0	15.2*				
Hungary	20.8*	10.9*	19.7*	21.4*			
Poland	35.3*	27.9*	9.1*	21.3*	16.9*		
Slovakia	0.0	3.1	0.0	0.0	0.0	16.7*	
Slovenia	0.0	0.0	0.0	0.0	94.1*	0.0	0.0

Note: The values refer to % ($\bar{Z}_{n,t}$) of cases with estimated convergence by all tests; * confirmed convergence (significant at 0.05 significance level).

Source: own

Since there is no known recent study that would apply a similar methodology to the regions of Central Europe, it is possible to compare our findings with the study by Le Pen (2011). In his study, the application of Pesaran's approach to 195 EU regions brought only very weak results on possible convergence processes. In general, it also identified the absence of the common stochastic trend among the regions as a major cause of violation of the convergence criterion. After all, conclusions about the rigidity of the method in the area of stationarity testing were discovered by Pesaran (2007) himself. Given these analogies, it can perhaps be assumed that our results (13.6% of confirmed convergence links) are consistent with general assumptions about the results of the applied methods and can thus be considered plausible.

Considering studies using different methodologies but focused on the same region, our results are consistent with the main findings of previous research on income convergence in Central Europe. Similarly to Crespo Cuaresma et al. (2016), Nagy and Siljak (2022), and Zdrazil and Applova (2016), we found the income convergence between regions. Kapidzic et al. (2022) argue that this is due to access to national funding and EU resources, while Nagy and Siljak (2022) claim that factors such as economic openness, inflation, and the integrity of government play a more significant role. However, Licchetta and Mattozzi (2023) point out that the process is slowing down. Further down, convergence between the own (inner-country) regions was confirmed for all countries (except Slovenia). This conclusion may be considered rather surprising, as it contradicts a number of previous studies, according to which inner-country disparities are increasing (Kokocinska & Puziak, 2018; Zdrazil & Applova, 2016). This discrepancy is likely explained by the difference in methodology, where previous studies applied different procedures and evaluated less recent data. We also found that Polish regions achieved the most convergence links, as they converged significantly with regions from all countries (except Slovakia).

However, we found that only some of the regions are engaged in the convergence process, which is similar to Markowska et al. (2022). This conclusion is evident from Fig. 1, which summarizes the intensity of convergence. This intensity is represented by the number of convergence relationships with other regions in which each region is involved (since the sample of 86 regions is examined in this study, the theoretical maximum value of intensity is 85). The intensity value for the regions with the highest numbers of convergence relationships is around 30. On the other hand, more than a third of the regions show only a low number of convergence relationships (8 or less).

Fig. 1 shows a "north-south belt" of regions that experienced convergence process more frequently. Interestingly, this belt is made up mainly of regions on the border of the former Iron Curtain. These are the regions of Austria, Czechia, Slovenia, the westernmost regions of Hungary, and the western half of Poland. Surprisingly, however, we see many white spots

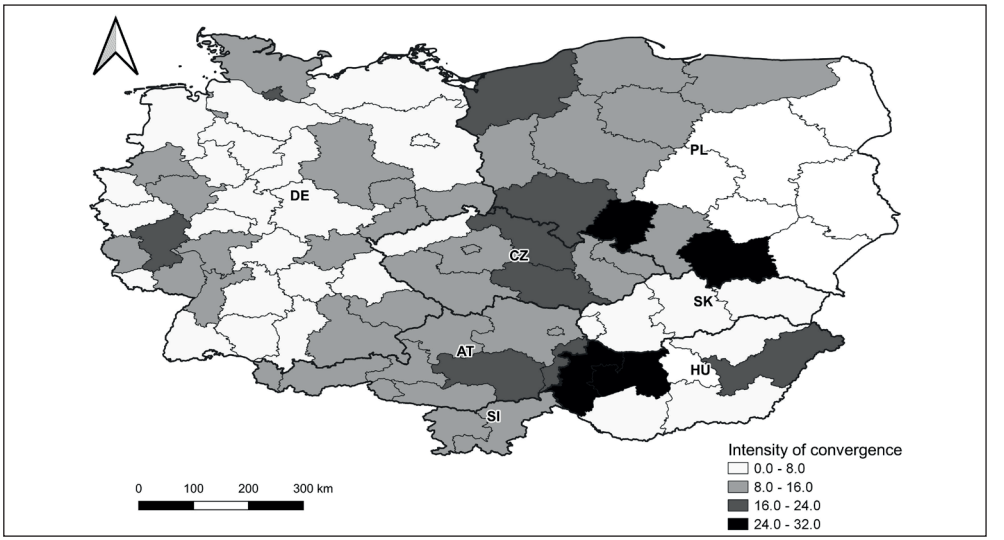

Fig. 1: Intensity of convergence in Central Europe

Source: own

(i.e., no or minimum convergence relationships) throughout Slovakia, the eastern regions of Poland, and Hungary. This observation aligns with the theoretical construct of club convergence, as explained in the literature (Basel et al., 2021; Sofi et al., 2023). Club convergence posits that clusters of regions sharing analogous characteristics or economic attributes tend to converge collectively. However, club convergence is not a rare phenomenon in Europe, since many empirical studies found some similar patterns (Drager et al., 2023; Kapidzic et al., 2022; Markowska et al., 2022).

Taking into account only transition countries, the most developed regions are included in the belt. This means that the least developed regions on the eastern border of Central Europe have not caught up with the convergence process. The benefits of EU membership, which should support convergence (Kapidzic et al., 2022; Rapacki & Prochniak, 2019), are therefore insufficiently reflected in these regions. The income in these poorest regions does not converge towards the level of their western neighbours, and hence does not create the conditions for increasing of well-being. Licchetta and Mattozzi (2023) argue this should be a result of the limited catch-up in total factor productivity growth. Prokop et al. (2021) make a similar point when they state that foreign knowledge and technology do not represent a major source of innovation and development in catching-up Central European countries. These regions cannot be considered winners of the convergence process, as described by Holobiuc (2020).

We also found that the regions of the most developed country in the sample (Germany) did not exhibit a high amount of convergence relationships. In terms of cross-country convergence, German regions converge only with some regions of Hungary and Poland. This challenges the traditional assumption that less developed regions will converge towards the more developed in terms of faster growth (Barro & Sala-i-Martin, 2004). In particular, our findings challenge the conclusions of Cieslik and Wcislik (2020), who believe that the regions of transition countries are converging towards Germany. We assume that the catching-up process in income is stronger towards the regions of Austria. In fact, Konya (2023) concludes similarly in his recent study and proposes to pay more attention to the convergence of transition countries with Austria.

The regions of the smallest countries in the sample, such as Slovenia and Slovakia, struggled to converge with the regions

of the more developed countries. Furthermore, despite witnessing income growth, the Slovak regions did not experience convergence with foreign regions. This highlights the complexities involved in achieving regional convergence, even within the context of economic integration and globalisation. This suggests that factors beyond country size, such as historical legacies, institutional frameworks, degree of globalisation, and the level of regional infrastructure, play a significant role in determining regional inequalities (Nagy & Siljak 2022). These findings correspond with the conclusions of Borsi and Metiu (2015), who argue that there is no unambiguous evidence of real income convergence in the enlarged EU. However, we can agree with the findings of Drager et al. (2023), Gligoric (2014), Kapidzic et al. (2022), and Markowska et al. (2022) that the convergence processes are valid only among some of the regions.

Conclusions

The aim of this paper was to assess the income disparities between the regions of the Central European countries. To achieve this aim, an approach based on time series cointegration analysis was used. We applied the probabilistic approach for the evaluation of disparities introduced by Pesaran, which is based on the assessment of a stochastic and a deterministic trend of time series. However, in our analysis, convergence criteria are tightened to increase robustness. In particular, we propose to require meeting both criteria, i.e., stationary and absence of unit root, instead of one for the acceptance of the cointegration condition. The significance of this modification became apparent when comparing the results of the stationarity and unit root tests.

The empirical analysis showed that despite the application of stricter conditions, the hypothesis of income convergence between Central European regions from 2003 to 2022 cannot be rejected. In particular, we found inner-country convergence in most countries. However, the involvement of individual countries in cross-country convergence varies widely. We found a “belt of convergence” made up of regions on the border of the former Iron Curtain. On the other hand, the intensity of convergence of the easternmost regions and of the westernmost regions is weak. Therefore, we assume that we can talk about confirmation of the club convergence, which has been indicated by some scholars. However, our results challenge the conclusions of previous research, according to which the transition economies of Central Europe are converging only towards the regions of Germany. Our results suggest that the convergence relationships towards the regions of Austria are more intensive.

Based on our results, it can be stated that income convergence occurs between the regions in Central Europe, suggesting that there is also a potential for a disparity decrease in standards of living and well-being of the population in the Central European regions in the future. From this conclusion, it can be inferred to a certain degree that the EU’s Cohesion Policy seems to be effective. However, this effectiveness is only partial as it is not evident in every region. The underlying question is how much it has actually impacted the developments mentioned above. We are aware that there are many factors that impact development trends and convergence trajectories, many of which are difficult to filter out. Although the research is limited by these facts, our findings provide access for better understanding of income dynamics in the Central European region. Moreover, it can also help to optimize the allocation of EU funding.

Finally, many interesting findings emerge from our analysis on regional income convergence in Central Europe, but for the discussion, we select only the most important conclusions. These results deepen the current research by showing significant differences in convergence patterns across countries. On the other hand, it also raised a number of new questions that need to be answered in further research.

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Soft total quality management and employee performance: The resonant effect of leader narcissism

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Abstract: *Stemming from the purpose of exploring the changes made by narcissism in the context of hospitality enterprises with total quality management (TQM) implementation, this study proposes a multi-level analytical framework taking into account the moderating effect of leader narcissism on the relationship between soft TQM practices and employee performance on the basis of the abilities, motivations, opportunities framework and the social information processing theory. The analysis of survey data from 1,155 employees from mid- to high-end hotels in two famous tourist cities in Vietnam allowed us to empirically test the relationship between these constructs. The findings showed that communication, teamwork, training and development create significant improvements in employee performances. More importantly, the moderating role for leader narcissism is confirmed in the relationship between training and development and employee performance. Therefore, the study highlighted theoretical implications related to a holistic approach to narcissism – the controversial psychological characteristics of leaders in the workplace. In addition, a number of managerial implications have been provided for hotel managers in enhancing the effectiveness of TQM implementation for improved performance through promoting the role of narcissistic leaders.*

Keywords: *Total quality management (TQM), soft TQM practices, narcissism, narcissistic leader, performance.*

JEL Classification: *M10, M12, M54.*

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Introduction

Total quality management (TQM) has been widely recognized as a new management theory for its potential to improve service quality, organizational efficiency and competitive advantage (Hwang et al., 2020). TQM is predicted to become the leading management model to respond to increasingly stricter requirements and greater global challenges of sustainable development. Moreover, TQM is not a fad in management, but a topic that still has great appeal to managers pursuing quality and excellence in the context of Industry 4.0. This new context requires scholars to re-evaluate the relevance, effectiveness and validity of core TQM practices, which opens avenues for

further research. Existing studies on TQM's impact often focus on organizational-level performances, with an emphasis on tangible aspects such as financial outcomes (Valmohammadi, 2011). People-related TQM practices, also known as soft TQM practices, focus on helping employees achieve their full potential and thus enhancing organizational performance (Prajogo & Cooper, 2017). However, few studies have linked soft TQM practices with individual-level outcomes and most of them have only considered job satisfaction, job involvement, turnover intention instead of employee performance (EP) (Vihari et al., 2022). Furthermore, the mechanism behind TQM's impact on EP has not been fully elucidated since the literature on TQM has rarely discussed the favorable conditions for this relationship or the intervention of contextual factors.

Narcissism, characterized by self-confidence, ambition, and high motivation for achievement, emerged as a new trend among leaders, is controversial topic as it can lead to success and also problematic behaviors (Yang et al., 2021). Organizational psychology literature has mostly concentrated on its negative impacts on employees and the organization, such as unethical behaviors and poor interrelationships; however, literature has not properly investigated narcissism in more complex relationships with organizational and employee factors (Huang et al., 2020). More specifically, the moderating effect of leader narcissism on the relationship between TQM and employee outcomes is still relatively small. According to the social information process (SIP) theory, employees' perceptions of what is going on in the organization importantly affect their attitudes and behaviors (Salancik & Pfeffer, 1978). In other words, narcissistic leaders could have a unique role in the organization by influencing employees' perception of TQM implementation, helping them to better grasp TQM philosophies and creating changes in their performance. This has given us the impetus to conduct an empirical study to explore the value and changes that a leader driven by a controversial trait (narcissism) could bring to the organization.

Moreover, exploration of TQM across a wide variety of contexts is needed to find out context-specific solutions. In the service sector, where personnel are the cardinal for quality, the linkage between TQM and EP is more attractive because the latter determines customer satisfaction and, ultimately, TQM's goals (Khan et al., 2019). Additionally, narcissism's role needs to be continuously examined in this interaction-intensive context to explore both its dark and bright sides. For this study, hospitality is particularly relevant as it creates momentum for economic growth and rapid breakthroughs after COVID-19, especially for developing countries (Zaman et al., 2021). The requirement for continuous improvement is also becoming more stringent to meet new customer requirements and adapt to competition from digital platforms; therefore, TQM is regarded as a "way of life" for the tourism and hospitality industry (Talib & Rahman, 2021). Research in the context of high pressure from customers may amplify the potential impact of narcissism.

A paucity of studies on TQM in the tourism and hospitality context have mainly considered TQM practices as predictors of organizational performance (Amin et al., 2017), but have not fully examined TQM's impact on employee outcomes or the potential intervention of leadership characteristics. In response to the call to explore this topic further, we attempted to answer the specific questions:

RQ1: How do soft TQM practices impact employee performance?

RQ2: What role does leader narcissism play in the relationship between soft TQM practices and employee performance?

Specifically, this paper empirically investigates the effect of leader narcissism as moderator on the relationship between people-related TQM practices and EP in the hospitality industry. This allows us to identify the appropriate conditions, related to the leader's behavior derived from their narcissistic personality trait, to maximize the effect of TQM implementation on improving EP.

This study contributes to the literature on TQM and organizational psychology in several ways. The first contribution comes from examining the relationship between TQM and EP considering the situational factor-leader narcissism-based on abilities-motivations-opportunities (AMO) framework and SIP theory. We also fill a research gap in investigating how changes in the effect of TQM implementations on employee performance come from situational variables such as narcissistic leaders. Secondly, this paper provides a positive perspective on the impact of narcissistic leaders

for organizations. The application of SIP theory also shows the important role of middle- and first-line managers – who have been less mentioned in TQM studies compared to top managers despite having a significant impact on employees' perceptions and attitudes about TQM implementation. The third contribution is related to the research context. In addition, the empirical evidence from mid-range and high-end hotels in emerging and developing Asian economies such as Vietnam, with the rapid recovery after the COVID-19 pandemic, could give meaningful suggestions for businesses in the hospitality industry.

The remainder of this paper will be opened with a review on TQM, EP, leader narcissism and the relationship between these constructs. Next, the analytical framework and the hypotheses will be explained. The methodology section will then introduce data collection and measures. The main findings will be highlighted, followed by discussions, theoretical and practical implications, limitations of the study, and future research.

1. Theoretical background

1.1 Soft TQM practices and employee performance

In the face of increasingly fierce competition and strict requirements, TQM is a holistic management philosophy with principles and practices that enable an enterprise to achieve superior quality and work toward business excellence based on cooperation within the organization (Babatunde et al.,2021). TQM revolves around three core values: adding value to customers, promoting innovation and moving toward sustainable development (Dahlgaard-Park et al., 2018). TQM practices are generally classified into hard and soft practices. Soft TQM practices are guided by the view that organizational quality is created by and is the responsibility of all individuals rather than a specific department within the organization. While hard practices form the heart of TQM, soft TQM practices still hold a worthy position by creating an enabling environment for successful TQM implementation in the long run and maintaining an engaged workforce (Hwang et al., 2020). Compared with hard TQM practices, soft TQM practices are more closely related to individual-level outcomes and need further empirical investigation (Vihari et al., 2022). EP refers to the actions, behaviors and outcomes of an individual, which are related to and contribute to the overall goals of the organization and constitute an important measure to evaluate the effectiveness of soft TQM practices (Atatsi et al., 2019). Although a positive relationship between TQM and EP has been argued, the mechanism behind this linkage is still ambiguous.

In this study, the AMO framework, which is commonly used to explain the link between human resource management and employees (Hwang et al., 2020), led us to explore more clearly the link between soft TQM practices and employee performance. The AMO framework assumes that performance is an outcome of a combination of employee variables: ability – skills and abilities needed to perform specific tasks; motivation – encouragement towards a specific role; and opportunity – context that allows employees to contribute to the organization (Lasrado, 2019). These variables are both separate and interrelated and complementary to each other (Shahzad, 2019). If TQM practices related to these variables are promoted, it will help employees better develop their potential. Ultimately, better results will be achieved for both the organization and the employees (Boxall, 2003; Yazdani, 2022). Specifically, soft TQM practices are necessary to enhance employee capabilities, motivate employees to excel in their efforts, and create a supportive environment for employees to achieve high performance.

Moreover, more effort is still required to adjust and flexibly implement TQM practices in service industries, including hospitality. The intersection point between TQM's core values and characteristics of the hospitality industry is people-oriented, towards excellence, based on cooperation, mutual trust and empathy (Anninos, 2018). Drawing from previous studies of TQM in the service sector along with successful real-world lessons, a set of TQM practices that are essential and relevant to this study are identified. Teamwork and communication are increasingly emphasized in the Industry 4.0 context (Babatunde, 2021). Teamwork is essential for successful TQM implementation, particularly in tourism businesses, because it allows for the seamless integration of different functions within the organization and the formation of effective teams (Vihari et al., 2022). Communication emphasizes information sharing between individuals and groups to enhance mutual understanding, which affects the attitudes, behaviors and

knowledge of employees (Bakotić & Rogošić, 2017). Empowerment, which involves delegating responsibility from top to bottom levels of management, psychologically impacts employees by making them more confident in their abilities, more proactive about their roles and responsibilities within the organization (Vihari et al., 2022). Training and development is a systematic process to promote the acquisition of skills, knowledge and attitudes to match job requirements and seize growth opportunities in the organization, thereby improving productivity, strengthening employee relations, and reducing turnover (Bakotić & Rogošić, 2017). Employee involvement motivates employees to show responsibility through actively connecting with team members, proactively giving ideas and participating in quality improvement activities (Tortorella et al., 2021). In general, to ensure effective TQM implementation and simultaneously enhance soft TQM's impact on EP, both selecting relevant practices and clarifying the underlying mechanism of their impact in specific contexts should be highlighted.

1.2 Leader narcissism as moderator of the relationship between soft TQM practices and employee performance

Narcissism has emerged in organizational psychology in the last few decades. It refers to a personal aspect that may bring value to the organization (Meier & Semmer, 2012). Narcissistic individuals are characterized by extreme self-love, admiration, concern about the self, are strongly aware of their abilities and advantages, and want to receive recognition from everyone (Mai et al., 2022). In this study, leader narcissism refers to a type of personality trait of a leader that encompasses grandiosity, self-confidence and charm (Zhou et al., 2019). This typical characteristic of a leader distinguishes them from managers possessing other prominent personality traits (Wong et al., 2017). Leader narcissism is recognized through narcissism-directed behaviors (Schyns, 2015). In other words, narcissistic leaders have outstanding social skills and intense charisma, allowing them to influence subordinates effectively. In addition, pursuing bold goals, promoting change, encouraging creativity, and the tendency to take great risks to achieve goals are also manifestations of leader narcissism (Campbell et al., 2011).

In managerial positions with the power, bolstered by risk, work pressure, and successes, leader narcissism plays a remarkable role in the organization (Gruda et al., 2021). Studies on the dark side of narcissism seem to predominate and describe narcissistic individuals by deficiencies in self-direction and self-identification, which lead to arrogance, excessive need for recognition and superiority, poor communication and interrelationships, lack of empathy and flexibility (Sosik et al., 2014). From a positive view, narcissistic leaders can offer great visions and breakthrough strategies and inspire powerful followers (Wang et al., 2021). Although a positive impact on organizational outcomes such as strategy implementation and performance has been mentioned (Mai et al., 2022), there is still a lack of empirical evidence about the role of leader narcissism in the relationship between TQM and EP. On the other hand, scholars have often described certain conditions under which leaders can develop the constructive narcissism aspect, such as a policy system, control systems, an advisory system, or social and legal barriers (Sosik et al., 2014). Narcissistic leaders also show their relevance and importance when enterprises stand in front of the innovation era because their foresight is paramount in a chaotic business context (Liao et al., 2019). In other words, it is necessary to evaluate narcissism in a specific context and situation with organizational constraints to underline its importance.

Looking at the relationship between leader narcissism, TQM practices and EP, several research gaps need to be addressed. First, although there is an intersection between these variables, there are few empirical studies examining the complex relationships behind these constructs. Second, testing the direct impact of soft TQM practices on EP is not sufficient; it is more important to understand how this relationship will vary under certain conditions or moderators. Leader narcissism needs more attention because of its growing popularity in work context and its controversial effects on the organization (Wang et al., 2021). Third, previous studies have often focused on the relationship between narcissism and individual-level variables, such as follower's attitudes and satisfaction (Yang et al., 2021). Expanding the search for different effects of leader narcissism in multilevel analysis is necessary and could allow the identification of specific contexts to promote

the positive aspect of narcissism. Fourth, with mixed results in studying narcissism depending on rating sources, there is still no convincing answer to the question of whether leader narcissism brings positive value to the organization in general and to EP improvement through TQM in particular.

For brevity, to deepen insights into narcissism and enrich the literature on TQM, this study evaluates the moderating role of leader narcissism in the relationship between soft TQM practices and EP. In addition, we examine the role of leader narcissism in the hospitality industry characterized by an interaction-intensive and highly volatile, uncertain post-pandemic environment (Zaman et al., 2021) with the expectation of exploring how this distinctive psychological characteristic of leader can make significant changes to the relationships between various variables within the organization.

1.3 Analytical framework and hypotheses development

In this study, AMO framework led us to explore more clearly the link between soft TQM practices and EP. Accordingly, soft TQM practices improve EP in different angles, by: (1) enhancing employees' knowledge, skills, and abilities in TQM; (2) stimulating motivation in using TQM-related abilities; (3) providing opportunities for employees to participate in the working environment and apply their ability related to TQM to improve work results. In other words, soft TQM could produce significant changes in EP through the enhancement and adjustment of employee skills, attitudes and behaviors (Yazdani, 2022).

Specifically, teamwork serves as the foundation for collaboration, enhances social dynamics, fosters a collaborative atmosphere between employees and management, thereby improves EP (Verma et al., 2022). Employee empowerment is associated with the transition from a traditional context to a collaborative and service-oriented context (Rahman et al., 2020). When employees are psychologically empowered, they will have a more positive orientation to their organizational role, more confident in their abilities, proactively seize opportunities to participate in quality activities and ultimately enhance EP (Assen, 2021). Communication is the backbone of any organization, promotes EP by creating a favorable environment for open and effective exchange between employees and managers, helps employees to better grasp TQM philosophies and have a stronger motivation to apply TQM-related understanding in their work process to improve EP (Fuentes-Fuentes et al., 2011). Training and development is also a significant driver of EP because this practices equips employees necessary knowledge and skills to meet new working challenges and offers them opportunities to achieve long-term career goals by applying their skills and abilities to improve performance (Amin et al., 2017). Employee involvement enhances the exchange of different thoughts and views between managers and employees, thereby promotes employee's positive attitudes towards quality and commitment to proactively create change in performance (Verma et al., 2022). Therefore, we postulate that:

H1a–e: Soft TQM practices (a – teamwork, b – employee empowerment, c – communication, d – training and development and e – employee involvement) positively impact EP.

The role of leader narcissism is grounded by SIP theory (Salancik & Pfeffer, 1978). Accordingly, based on information provided by the social environment and processed through social information process, employees form their views and attitudes toward the organizational context. Employees combine information from the context and their leaders to shape their perception of the surrounding environment and adjust their working behavior. In other words, the psychological characteristics of leaders influence the perception and behavior of subordinates. Narcissistic leaders with power and charm can make followers believe in the direction of TQM implementation, lead and change followers' perception of TQM practices, thereby enhancing the effect of these practices on EP. Empirically, the moderating role of the leader narcissism has been mentioned for the relationship between plans, strategies, implementation of models at the company and different outcomes (Shabbir & Kousar, 2019). The positive effects of narcissism can be suggested on the grounds that narcissistic leaders always aspire to create an admirable legacy to demonstrate their influence and importance (Simsek et al., 2010). In addition, some narcissistic leaders are willing to listen to subordinates and keep a humble attitude when working with others (Carnevale et al., 2018), thereby they could be associated with the effectiveness of employee involvement, communication,

and employee empowerment practices. Next, the impact of training and development depends on the leader's assessment (Khan et al., 2019). While narcissistic leaders have very high demands on their subordinates, they can motivate employees to put more effort in the training process and show it through EP. Teamwork emphasizes the close association between individual achievement and collective performance, so leader narcissism is expected to be able to enhance the impact of this practice on EP (Nevicka et al., 2018). Thus, these arguments prompted us to hypothesize that:

H2a–e: Narcissism positively moderates the relationship between soft TQM practices and EP.

Also, under certain conditions or environmental uncertainty, narcissism can be viewed more positively (Anninos, 2018). Therefore, these research hypotheses will be tested in the challenging and risky context of the hospitality industry after COVID-19 shock.

2. Research methodology

2.1 Research procedure

Hospitality industry, which constitutes an important driving force for Vietnam's economy with the ability to create multiple jobs and maintain a rapid growth rate (VNAT, 2020), is the research context of this study. Hospitality businesses have shown a strong recovery from COVID-19 and are facing the challenge of continuously improving performance to meet the increasing demands of customers (VNAT, 2022a). Therefore, TQM has become an indispensable direction for success in hotels (Talib & Rahman, 2021). Meanwhile, despite TQM implementation, several quality and performance issues still need to be further explored (Phan et al., 2022).

We conducted research, from 5–9/2022, at hotels in Hanoi and Ho Chi Minh City – Vietnamese famous destinations attracting nearly 23.7 million tourist arrivals by 2022 and contributing to the total tourism revenue of about USD 7.4 billion, nearly 70% compared to the year before COVID-19 pandemic (HTD, 2023; GEIP, 2023). Mid- and high-end hotels are focused because these groups face stringent quality requirements, aim for high service standards, and generate significant revenue and jobs for the market (Vij et al., 2021).

Data was collected from 1,155 employees from 107 3–5-star hotels in the list regulated by the Vietnam National Administration of Tourism (Tab. 1). We contacted the hotel's representatives to ask them to send the questionnaire to at least 20 employees. Respondents are non-managerial employees in different departments of the organization to minimize response bias. We enclosed the questionnaire with a cover letter to introduce the purpose of the study, encourage respondents' voluntariness and pledge to keep the answers confidential.

The questionnaires were sent to 1,839 employees, of which 1,164 employees responded (response rate was 63.3%). After removing invalid responses, 1,155 questionnaires were included in the analysis. This sample size is larger than 170 (5 times the number of observed variables) to ensure the reliability to analyze according to Hair et al. (2013). Women accounted for 65.7%, people with a university education or higher accounted for 54.8%, and people aged over 35 accounted for 50.6%.

The partial least squares structural equation modeling (PLS-SEM), with the use of Smart PLS 4.0, is appropriate for this study to examine the complex relationships between variables under small sample conditions (Hair et al., 2017). After testing the reliability and validity of the model, the research hypotheses were tested based on the results of the structural model.

Tab. 1: Sample descriptions

	3-star	4-star	5-star	Total
Number of hotels participating in the survey in Hanoi and Ho Chi Minh City	41	32	34	107
Number of hotels in Hanoi and Ho Chi Minh City	50	36	37	123
Number of hotels in Vietnam	630	311	234	1,175

Source: VNAT, 2022b

2.2 Measurement scales

Measurement scales have been developed based on solid theoretical foundations and verified in previous studies. Soft TQM scales measure employees' perceptions of the implementation of people-related TQM practices, including *teamwork*, *employee empowerment*, *communication*, *training and development*, *employee involvement* (Assen, 2021; Hwang et al., 2020; Prajogo & Cooper, 2017; Valmohammadi, 2011). *Employee performance* scale, adapted from Song et al. (2018), refers to the self-assessment of employees about their in-role performance at the organization. *Leader narcissism* scale is adapted from Li and Tong (2021) and Sosik et al. (2014). *Leader narcissism* is assessed based on how employees perceive their direct leader's behavioral features and personality traits in various aspect, such as high aspiration, self-centered person, thinking in unusual way or condescending behavior in relations with others (Tab. 2). The questionnaire was built with a section to fill in demographic information and 34 questions corresponding to items designed in the form of Likert-5 with 1 corresponding to strongly disagree and 5 to strongly agree.

3. Results

3.1 Measurement model

The reliability and validity of constructs were determined based on factor loadings, composite reliability, and average variance. Cronbach's alpha and composite reliability of all constructs exceed the acceptable threshold of 0.7 (Tab. 2). Indicator reliability is also confirmed when the outer loadings are within an acceptable range of 0.704 to 0.903. Convergent validity is expressed through AVE values that are all greater than 0.5. With self-reported data from a single source, we tested the occurrence of common method bias based on the suggestion of Kock (2015). The VIF values of the structures are all less than the threshold of 3.3, indicating that the common method bias issue does not appear.

The Fornell-Larcker criteria were used to test discriminant validity. The analysis results showed that discriminant validity is confirmed

Tab. 2: Analysis results of measurement model – Part 1

Latent variable	Indicators	Convergent validity		Internal consistency reliability		Discriminant validity (HTMT confidence interval does not conclude 1)	Collinearity statistics
		Outer loadings	AVE	Composite reliability	Cronbach's alpha		
***Teamwork* (*TWK*)**	Involvement in quality improvement teams	0.796	0.654	0.883	0.825	Yes	1.564
	Establishment of cross-functional teams	0.797					
	Available resources for quality-related teams	0.832					
	Willingness to put out for the sake of the teams	0.810					
***Employee empowerment* (*EMP*)**	Encouraging employees to fix problems	0.760	0.598	0.881	0.837	Yes	2.917
	Providing resources to employees to correct quality problems	0.864					
	Technical assistance for solving quality problems	0.704					
	Problem-solving network for solving quality problems	0.791					
	Autonomy in determining how work is performed	0.738					

Tab. 2: Analysis results of measurement model – Part 2

Latent variable	Indicators	Convergent validity		Internal consistency reliability		Discriminant validity (HTMT confidence interval does not conclude 1)	Collinearity statistics
		Outer loadings	AVE	Composite reliability	Cronbach's alpha		
***Communication* (*COM*)**	Receive information about the goals	0.800	0.601	0.883	0.834	Yes	1.490
	Receive information about customer's evaluation	0.759					
	Receive information about how to do the job	0.770					
	Receive information about superiors expectation	0.773					
	Receive information from colleagues	0.775					
***Training and development* (*TDV*)**	Available resources for quality-related training	0.769	0.609	0.886	0.840	Yes	1.372
	Quality-related training for all employees	0.751					
	Training on the "total quality and continuous improvement" concepts	0.801					
	Employees' career aspirations	0.813					
	Career paths of employee	0.767					
***Employee involvement* (*EIN*)**	Involvement in continuous improvement	0.791	0.711	0.880	0.803	Yes	2.800
	Involvement in quality-related decision-making process	0.903					
	Consideration of employees' suggestions on quality	0.831					
***Leader narcissism* (*NAR*)**	High level of aspiration	0.755	0.568	0.913	0.891	Yes	2.114
	Attempt to stretch limits	0.713					
	Self-centered person	0.775					
	Center of attention	0.776					
	Thinking in unusual way	0.760					
	Appreciation of intellectual and cognitive matters	0.762					
	Condescending behavior in relations with others	0.761					
	Inflated view of him/herself	0.723					

Tab. 2: Analysis results of measurement model – Part 3

Latent variable	Indicators	Convergent validity		Internal consistency reliability		Discriminant validity (HTMT confidence interval does not conclude 1)	Collinearity statistics
		Outer loadings	AVE	Composite reliability	Cronbach's alpha		
Employee performance (*EP*)	Performing tasks that are expected	0.808	0.653	0.883	0.824	Yes	
	Fulfilling responsibilities in job description	0.796					
	Meeting job performance requirements	0.820					
	Completing assigned duties	0.809					

Source: own

Tab 3: Analysis results of discriminant validity

	Employee performance	*Leader narcissism*	*Teamwork*	*Employee empowerment*	*Communication*	*Training and development*	*Employee involvement*
Employee performance	**0.808**						
Leader narcissism	0.350	**0.753**					
Teamwork	0.346	0.500	**0.809**				
Employee empowerment	0.181	0.511	0.288	**0.773**			
Communication	0.483	0.477	0.379	0.253	**0.775**		
Training and development	0.298	0.455	0.326	0.213	0.354	**0.781**	
Employee involvement	0.142	0.477	0.249	0.791	0.259	0.181	**0.843**

Source: own

when the correlations between the structures are all smaller than the square root value of AVE (Tab. 3).

3.2 Structural model and moderating effect

The structural equation model examination allows us to discover the relationship between latent variables. Model fit indexes of measurement model all ensure the acceptability recommended by Hair et al. (2013). *Communication*, *teamwork*, *training and development* practices positively impact *EP* at the 0.05 significance level (Tab. 4). Therefore, *H1a*, *H1c* and *H1d* are supported.

The adjusted R^2 value showed that 28.9% of the variance in *EP* is explained by the exogenous variables mentioned in the model. The coefficient f^2 allows us to evaluate and compare the impact of each independent variable on the dependent variable (Hair et al., 2013). According to Cohen (1988), the effect size of *communication*

Tab. 4: Path coefficients

Hypothesis	Original sample	Sample mean	Standard deviation	*T*-statistics	*p*-values	Results
H1a*: *Teamwork* → *Employee performance	0.121	0.121	0.051	2.351	0.019	Supported
H1b*: *Employee empowerment* → *Employee performance	0.063	0.072	0.068	0.920	0.357	Rejected
H1c*: *Communication* → *Employee performance	0.354	0.353	0.057	6.187	0.000	Supported
H1d*: *Training and development* → *Employee performance	0.110	0.116	0.045	2.443	0.015	Supported
H1e*: *Employee involvement* → *Employee performance	−0.076	−0.079	0.068	1.116	0.264	Rejected
Leader narcissism* → *Employee performance	0.060	0.065	0.059	1.011	0.312	Rejected
H2a*: *Leader narcissism* × *Teamwork* → *Employee performance	−0.090	−0.088	0.058	1.568	0.117	Rejected
H2b*: *Leader narcissism* × *Employee empowerment* → *Employee performance	0.119	0.103	0.073	1.637	0.102	Rejected
H2c*: *Leader narcissism* × *Communication* → *Employee performance	−0.106	−0.110	0.057	1.845	0.065	Rejected
H2d*: *Leader narcissism* × *Training and development* → *Employee performance	0.122	0.124	0.051	2.406	0.016	Supported
H2e*: *Leader narcissism* × *Employee involvement* → *Employee performance	−0.087	−0.065	0.076	1.140	0.255	Rejected

Source: own

is 0.120 indicating a small effect. *Employee performance* Q^2 value is 0.254, according to which, the studied soft TQM practices are related to *EP* at a moderate level (Hair et al., 2017).

Following the testing moderation in a path model, the relationship between the construct *training and development* and *EP* is assumed to be moderated by *leader narcissism* at the significance level of 0.05 (Fig. 1). The result provides clear support for hypothesis *H2d* that *leader narcissism* has a resonant effect on the relationship between *training and development* and *EP*. In other words, the higher the *leader narcissism*, the stronger the relationship between *training and development* and *EP* (Fig. 2).

4. Discussions, implications and future research

4.1 Discussions

This paper not only provides a meaningful answer to the question "what" TQM practices should be implemented but also discovers "how" optimal conditions enable the impact of these practices.

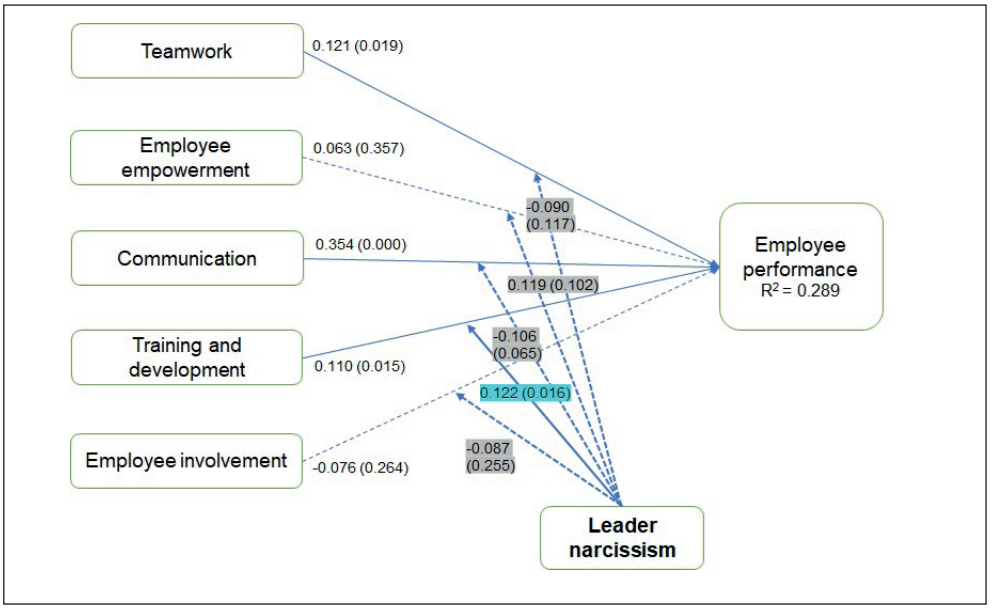

Fig. 1: **Structural model assessment result**

Source: own

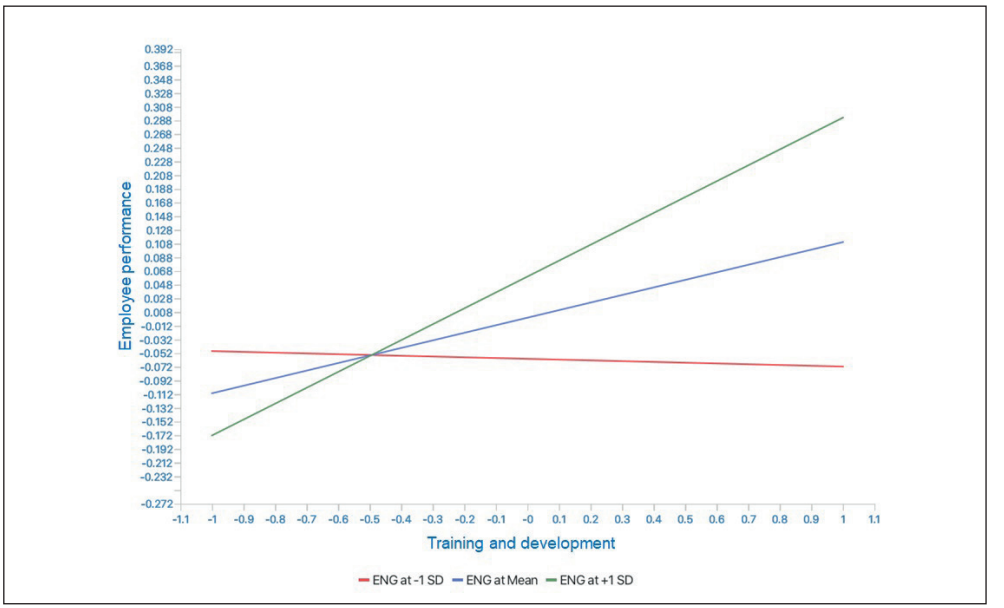

Fig. 2: **Moderating effect of *leader narcissism* on the relationship between *training and development* and *employee performance***

Source: own

The analysis results firstly showed that soft TQM practices (*communication*, *teamwork*, and *training and development*) significantly improve *EP*. This provides additional empirical evidence for the statements of Babatunde (2021) as these practices become more imperative in the context of Industry 4.0. In the hospitality industry, open communication allows TQM philosophies to penetrate deeply into the practice of each individual (Hietschold et al., 2014). Similar to the results of Hwang et al. (2020), *teamwork* practice reflects TQM's quality-oriented culture with a focus on outstanding performance based on a team-based organizational structure and harmonious cooperation among members. This study also confirms existing results (Assen, 2021) in the field of hospitality that *training and development* significantly improve *EP* and maintain service quality by enhancing of employee competencies and personal abilities related to continuous improvement.

In addition, an unexpected result has brought a new perspective to previous studies. Dissimilar to studies of Assen (2021) and Prajogo and Cooper (2017), this study has not noted a significant impact of *employee empowerment* and involvement on *EP*. This result could be explained by changes in the business environment after the COVID-19. After facing a long period of social isolation, burnout and loose association with the organization, employees feel apprehensive, need support from leaders to capture the letter O in AMO framework – the opportunity to become more involved in TQM implementation and take on responsibilities (Malik & Sanders, 2021). Therefore, delegating power and encouraging participation in the quality improvement process could not lead to a significant change in *EP*.

Next, this study clarified the role of narcissistic leaders in enhancing the impact of *training and development* practice on *EP*. Contrary to studies that have recognized narcissism as a dark characteristic of leaders (Gruda et al., 2021), this study revealed that narcissism can have resonant influence on TQM implementation in organizations. Specifically, when employees feel that leaders have a narcissistic personality, the positive impact of *training and development* on *EP* becomes stronger. On the one hand, consistent with SIP theory, the presence of *leader narcissism* significantly modifies employees' perceptions of TQM. Combined with AMO framework, these leaders reshape the appropriate attitude (letter A) of employees towards *training and development*, promote stronger motivation (letter M) in self-development, and help them seize important opportunities (letter O) for their career development. On the other hand, narcissistic leaders could widely spread their outcomes-oriented approach to employees, thereby making them more proactive in learning, increasing the effectiveness of training activities. In terms of employee development, narcissistic leaders inspire efforts and strive constantly to shine in their careers, that helps employees focus on long-term personal development. This further extends the previous study of Volmer et al. (2016) to clarify the link between leader narcissism and employees' career development. Certain organizational contexts can create opportunities for narcissistic leaders to realize their ambitions by giving them power and authority (Shabbir & Kousar, 2019). TQM implementation will be favorable condition for the expression of the role of leaders as an important prerequisite to lead the quality orientation to subordinates, to help employees easily achieve certain progress in their performance. This result also reinforces the view of leader narcissism as a holistic concept. With their ambition and charisma, narcissistic leaders conveniently develop and communicate compelling visions to their subordinates, then motivate them to focus on improving their personal capabilities and long-term career plans aligned with the vision of the organization.

4.2 Implications, limitations and avenues for future research

Theoretically, this study provides profound implications by firstly underlining soft TQM practices, which are appropriate to the contemporary context. While much of the current research focuses more on identifying an exhaustive set of TQM practices related to performance improvement (Sabbagh et al., 2019), it can be difficult to prioritize the implementation of these practices. This study focuses on practices that will meet the research needs of TQM in the context of the complex, post-crisis business environment and uncertainty of the hospitality industry. Second, we explain the interwoven relationship between TQM practices, leader's psychological trait and EP based on the guidance of AMO framework and SIP theory.

Considering leader narcissism as a condition enhancing the effect of soft TQM practices on EP highlighted the importance of situational factors. In addition, it is necessary to look at the concept of narcissism from a holistic approach so as not to ignore its potential impacts on the organization and employees. Third, studies on TQM implementation should properly focus on the human factor. The explanation of changes in EP should come from employees' attitudes and perceptions towards appropriate behavior, rather than just behavior. Fourth, the middle and first-line leaders, who have proximal and direct interactions with employees, need to be emphasized. Especially, when they are narcissistic, they will play a key role in enhancing the effect of TQM implementation by making a great contribution to changing the attitudes and behavior of subordinates.

Practically, several recommendations for hotel managers could be drawn from this study. Firstly, TQM implementation needs to be innovated and adjusted to suit the new context of the hospitality industry and the requirements of Industry 4.0. It is necessary to take advantage of digital transformation and quality information systems in the organization for effective communication, thereby improving EP (Babatunde, 2021). Leaders need to be fully informed about the changes related to TQM implementation and receive feedback from employees to promptly overcome problems that may affect EP. The implementation of teamwork practice requires hotel managers to form effective teams and encourage a spirit of cooperation, sharing and understanding among team members. This leads to positive attitudes, improves performance and creates changes in the quality of work-life of employees (Hwang et al., 2020). For training and development practice, accommodation businesses should invest in training employees to quickly adapt to new requirements from Industry 4.0 and customers (Khan et al., 2019). Additionally, supporting and motivating employees to define a clear career development path should be focused to arouse employees' interest and initiative in participating more deeply and proactively in TQM activities and continuous improvement (Assen, 2021).

Secondly, the implementation of soft TQM practices should not only be concerned with expanding practices implemented but should also pay attention to increasing the influence of each practice on EP through moderators such as leader narcissism. The role of narcissistic leaders, especially those who directly supervise employees, should be emphasized because employees are not only passively receptive to TQM practices, but cognitive processes are actively interpreted and governed by various situational factors, especially under the influence of the leader (Hwang et al., 2020). Besides, although narcissism shows a positive moderating role, appropriate mechanisms and policies are still needed to ensure this constructive impact of leader narcissism on the organization, such as conducting regular meetings with top managers to maintain the awareness of narcissistic leaders in line with the organization's quality orientation, regularly monitoring employees' evaluations of their supervisors.

As a limitation, although PLS-SEM allowed to explore potential relationships between constructs at multiple levels, other analytical models can also be applied to further explanation of the obtained results. Specifically, the role of leader narcissism being considered in the post-COVID-19 context is based on cross-sectional data, so longitudinal research could be conducted to seek more systematic conclusions. This will allow the development of timely interventions to encourage the positive effects of narcissism. Besides, this study examined the relationship between soft TQM practices, leader narcissism and EP based on a single source of survey data. Future studies may further explore the role of leader narcissism and provide more specific explanations through in-depth interviews, case studies, or other qualitative methods.

Conclusions

Inspired by the emerging requirements for deeper exploration of TQM implementation in the hospitality industry in light of Industry 4.0 and the ongoing debates about narcissism, this study examined the moderating role of leader narcissism in the relationship between soft TQM practices and EP based on AMO framework and SIP theory. The analysis of data provided by 1,155 employees of mid- and high-class hotels in Hanoi and Ho Chi Minh City in Vietnam has clarified the positive impact of communication, teamwork, and training and development on EP. In addition, the moderating effect of leader narcissism on the relationship between training and development practice and EP. This paper further contributes

to the literature on TQM and organizational psychology through empirical evidence on the complex relationships between organizational variables, leader psychological trait, and employee outcomes. The study also provides important implications for managers in enhancing the effectiveness of implementing soft TQM to improve EP by strengthening the role of leaders who are characterized by narcissism.

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Energy companies' readiness for the digital transformation of the purchasing process

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Abstract: *Social and economic developments, the dynamic geopolitical situation, and climate policy changes are exerting an increasingly significant influence on stakeholders in the energy sector. In recent years, the sector has undergone a period of dynamic change, during which there has been a notable increase in awareness of the potential for digital transformation within the sector. A specific process that ensures the security and stability of supply is the purchasing process. The objective of this article is to identify the mechanisms that facilitate and impede the digital transformation of the purchasing process in energy companies in Poland. The research employed a qualitative exploratory methodology based on interviews with procurement executives from Polish energy companies. The findings of the research, together with their subsequent analysis, enabled the identification of ten factors that act as impediments to the digital transformation of the purchasing process in energy companies in Poland. The article puts forward five mechanisms that could assist in overcoming the identified obstacles to transforming the purchasing process. The study emphasizes the significance of implementing effective change management and business digitalisation strategies to facilitate the digital transformation of purchasing process.*

Keywords: *Digital procurement transformation, purchasing, supporting mechanisms, barriers.*

JEL Classification: *M15, M21, O31, O32.*

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Introduction

The digital transformation that has occurred over the past few decades has resulted in significant changes across numerous business sectors. The energy sector has been subject to some of these changes, but recent developments suggest that the digital transformation of the energy sector is intensifying and accelerating. It is becoming increasingly evident and that the operation of the energy sector is becoming critically dependent on digital technologies.

In the recent years, there has been a notable increase in the number of studies examining the impact of digitalisation on the procurement process. The research is conducted from a variety of perspectives, including change management transformation, innovation, sustainability, value chain analysis and the application of agile project management methodologies. In examining the factors influencing the digitalisation of the purchasing process, researchers identify both barriers and opportunities, with a particular focus on social and organisational factors.

Previous studies have analysed specific technologies affecting the purchasing process, including blockchain (Hofbauer & Sangl, 2019;

Özkan et al., 2021), artificial intelligence (Jahani et al., 2021; Roth & Nikolla, 2020), business process automation (van Hoek et al., 2022; Viale & Zouari, 2020) and big data analytics (Srai & Lorentz, 2019). Furthermore, the literature also includes arguments for the necessity of modifying procurement process through digitalisation (Corejova & Chinoracky, 2021; Fallahpour et al., 2021). Additionally, there is also a growing corpus of research examining the impediments to digitalisation, specifically, the factors that impede the implementation of digital technologies in the purchasing process (Cichosz et al., 2020; Xu et al., 2021) and assessing the opportunities and potential benefits of purchasing processes digitalization (Cichosz et al., 2020; Yevu et al., 2021).

The aforementioned works have advanced the knowledge of purchasing process digitalisation, thereby facilitating their digital transformation. However, it was evident that a greater focus on the energy sector was required.

The values presented in Figs. 1–2 serve to substantiate the limited number of publications in the fields of purchasing process digitalisation and procurement digitalisation. Since 2019, there has been a notable increase in interest in the topics of purchasing process digitalisation and procurement digitalisation, which serves to confirm the relevance of the issues discussed in the article. It is notable that a search for the term “energy sector” or “energy company” in the Scopus database did not yield any results, indicating a significant research gap in the digitalisation of the purchasing process in an energy company.

The objective of this research is to address the aforementioned research gap by answering the following research question:

RQ: What mechanisms facilitate and impede the digital transformation of purchasing processin the energy companies in Poland?

Our theoretical perspective is informed by the findings of Lorentz et al. (2021), which identify new states or opportunities driven by the implementation of digital initiatives that enable value creation for the organisation in the purchasing process, as well as improvements in the efficiency of the purchasing process are defined as mechanisms (Lorentz et al., 2021; Srai & Lorentz, 2019).

We base our conclusions on qualitative data from 11 procurement managers from 8 Polish energy companies.

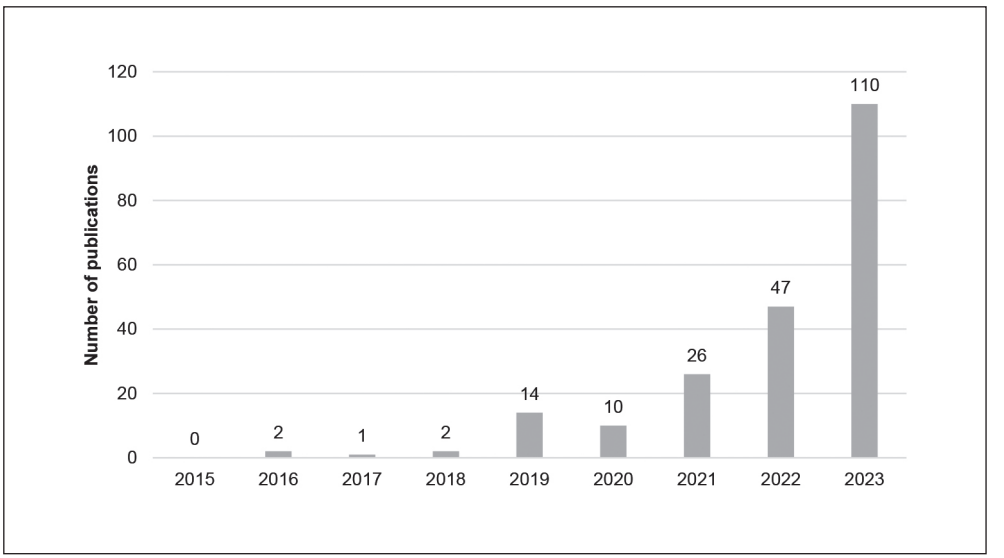

Fig. 1: **Distribution of scientific publications with the keywords “digitalisation” and “purchasing” in the Scopus database in 2015–2023**

Source: Scopus database

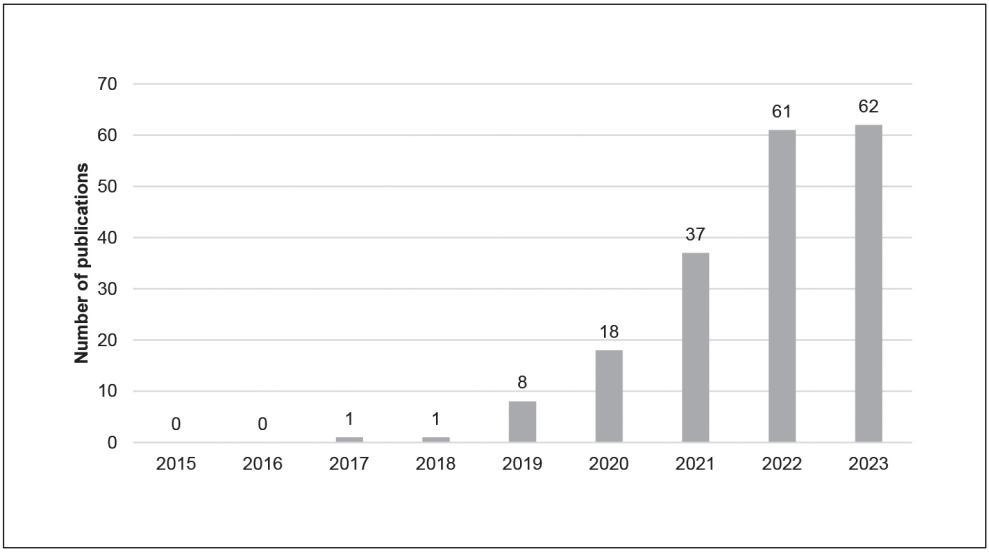

Fig. 2: **Distribution of scientific publications with the keywords "digitalisation" and "procurement" in the Scopus database in 2015–2023**

Source: Scopus database

1. Theoretical background

1.1 Specificity of the purchasing process in the energy sector

In accordance with van Weele (2010), the purchasing process can be defined as the management of an enterprise's external resources in a manner that ensures that the supply of goods, services, production capacity, and knowledge necessary for the operation, maintenance, and management of the enterprise's primary and ancillary is obtained at the most favourable terms (van Weele, 2010).

In the van Weele model, the purchasing management process takes into account the criterion of management levels and is divided into two groups: strategic (tactical) purchasing and operational purchasing. Strategic purchasing encompasses operational strategies and long-term plans. This group encompasses the activities of defining specifications, selecting suppliers, contracting. The role of strategic purchasing is to establish the most favourable circumstances for the execution of operational purchases. Operational purchasing is the activity that ensures the ongoing implementation of the purchasing process, including deliveries. This includes placing an order, monitoring delivery, processing payments, evaluating the implementation, as well as returns management. In this article, we adopt a perspective of the purchasing process that is consistent with that proposed by van Weele (2010).

The purchasing process in energy companies is characterized by a number of distinctive features, which can be attributed to the nature of the business and the specific requirements of the sector. This is primarily attributable to the fact that the energy sector plays a pivotal role in the functioning of the state, society, and economy (Geißler et al., 2021). The energy sector has undergone significant and rapid in recent years. Initially, these changes were driven by the necessity to comply with climate policy requirements. However, now the principal factor influencing change in the sector, including alterations in the energy mix (the structure of energy production according to the criterion of energy carriers), is the necessity to become independent of fossil fuels supplied by Russia in order to guarantee the stabilisation and security of energy supplies (Balsalobre-Lorente et al., 2023).

The energy sector is subject to complex and rigorous regulatory framework governing

the procurement of raw materials, technologies, and services. Therefore, it is incumbent upon energy companies to comply with the relevant safety, quality, and environmental protection regulations and to refrain from engaging in any monopolistic practices (Gołąbeska & Harasimowicz, 2023).

A substantial proportion of transactions within the energy sector entail considerable investment. These contracts are based on long-term agreements that guarantee the continuity and stability of supplies of energy raw material supplies (e.g., gas, coal) or services (e.g., the renovation and modernisation of facilities). Energy companies typically procure substantial quantities of raw materials, equipment, services, and sophisticated technologies, which necessitate sophisticated management processes, particularly in the areas of planning, specialized knowledge, and a comprehensive grasp of technical specifications and industry standards. The energy sector is characterized by a high degree of dependence on commodity prices. Consequently, energy companies must consider the inherent risks associated with the volatility of energy and raw material prices, as well as currency exchange rates, when undertaking purchasing activity. This necessitates the utlilisation of price indexation mechanisms in order to mitigate potential adverse effects.

It is common practice among energy sector entities to seek out new and more efficient technologies and solutions with the aim of guaranteeing the uninterrupted and stable provision of energy. This necessitates the monitoring of trends, the testing of new products, and the collaboration with suppliers of innovative solutions. Furthermore, ensuring the continuity of energy supplies necessitates a focus on the security of raw material supplies and infrastructure. It is thus incumbent upon the purchasing process to take into account the issues pertaining to the various sources of supply and their stabilization. The continuity and stability of energy supplies are contingent upon the minimization of failures within the network. The deployment of new technologies based on artificial intelligence algorithms and advanced forecasting plays an indispensable role in the prediction of failures, thereby enabling a rapid response and the minimization of losses.

In the light of mounting environmental consciousness, energy companies are progressively incorporating environmental and social benchmarks into their supplier selection processes. Consequently, the purchasing process in energy companies necessitates the input of specialists from a range of disciplines to guarantee an effective and sustainable approach to the implementation of the purchasing process. The success of the sector's digital transformation process is contingent upon meticulous preparation and implementation, as these factors directly influence the rate of change.

1.2 Digital transformation of the purchasing process

The majority of researchers concur that digital transformation is accompanied by the advent of a novel business model, shaped by the influence of implemented digital technologies (Śledziewska & Włoch, 2020). It may, therefore, be posited that the advent of digital transformation will result in a shift in the perception of the purchasing process within organizational contexts, whereby it will cease to be regarded as an administrative and clerical function and instead become viewed as a strategic value-generating function (Bienhaus & Haddud, 2018).

In recent years, there has been a growing recognition among organisations of the value of streamlining their purchasing process (Bals et al., 2019; Gottge et al., 2020). These values are most appreciated in the public sector (Kagondu, 2023), the manufacturing sector (Palange et al., 2021), the healthcare sector (Omar et al., 2021) and the financial sector (Edunjobi, 2024). Digitalisation represents is the dominant direction for improving purchasing process (Kulikowska & Wszendybył-Skulska, 2021). The purchasing process digitalisation is associated with enhanced outcomes, particularly at higher levels of maturity within the purchasing function of an organization. The organisation is perceived as a key, strategic one. Consequently, the purchasing process will be regarded as a "profit centre" within the organisation, in contrast to its previous status as a "cost centre" as in the past (Ocicka, 2019). The majority of companies are still in the initial stages of integrating new digitalisation concepts into their procurement process (Bhuiyan et al., 2024).

The tools used to digitize the purchasing process have developed in line with technological advancements, resulting in an increased scope of integration and the degree of automation

within the purchasing process (Glas & Kleemann, 2016). The first tool for the digitalisation of the part of the purchasing process, specifically the stage responsible for planning production material requirements, emerged in the 1960s. The tool was designated by the acronym MRP (material requirements planning). In the subsequent phase of development, the digitalisation tool was also employed to facilitate the planning of fixed asset requirements and, indeed, human resources, leading to the advent of a tool designated MRP II. Subsequently, in the early 1990s, ERP systems were introduced with the objective of providing support for management functions. Integrated ERP systems underwent further evolution, with the development of new system modules and new functionalities being developed. By the early 21st century, enterprise resource planning (ERP) systems had evolved to the point where they could communicate with other information technology (IT) systems, such as a purchasing platform. The principal objective of an ERP system is to facilitate the integration of all departments within an organisation through the utilisation of a unified database. ERP class systems were designed as internal systems, with the primary function of integrating the various functions within the organization. The purchasing process within an ERP system is concerned with the management of orders and expenses. It was not until the advent of ERP II that communication with external partners and integration with their systems became a possibility. The emergence of digital tools for the purchasing process digitalisation, enabling electronic purchasing (e-procurement), was driven by a market need. Consequently, the most recent iterations of ERP systems incorporate embedded digital technologies, including artificial intelligence, machine learning, blockchain, and RPA. In order to address the deficiencies in functionality observed in ERP-class systems, solution have emerged in the form of purchasing platforms. The advent of purchasing platforms has facilitated the electronic organisation of the source of supply electronically (e-sourcing), encompassing electronic negotiations in successive RFX rounds or auctions.

The advent of SMAC/BRAID technologies (social media, mobile technologies, analytics and big data, cloud services/blockchains, robotics, automation of knowledge work, internet of things, digital fabrication) has been identified as a significant development in the field of management (Śledziewska & Włoch, 2020). This has facilitated the accelerated evolution of digital tools for streamlining the purchasing process (Willcocks, 2016). In her analysis of SMAC/BRAID digital technologies, Kulikowska (2023), concluded that the common denominator of these technologies is data and integration, which affects the creation of intelligent process automation (IPA). Tab. 1 illustrates the potential applications of SMAC/BRAID digital technologies in the purchasing process.

Tab. 1: Examples of using SMAC/BRAID technology in the purchasing process – Part 1

Digital technology	Examples of application in the purchasing process
Social media	The utilisation of social media can facilitate the core function of procurement, namely the management of supplier relationships. From the perspective of a source of information about the supplier market and products, social media can be employed to create supplier profiles and to develop a purchasing strategy, i.e., they support the activities of the purchasing management process at the strategic level (Diba et al., 2019).
Mobile technologies	The function role of mobile technologies in the purchasing process is to facilitate the transfer of activities related to acceptance in systems that support the purchasing and procurement process (e.g., ERP system or purchasing platform) or participation in an electronic auction. Such activities can be undertaken in a mobile application, thereby ensuring flexibility and enhanced accessibility, provided that a suitable application is installed. Examples of suitable applications include such as SAP Ariba procurement and oneplace (Dalton et al., 2024).

Tab. 1: Examples of using SMAC/BRAID technology in the purchasing process – Part 2

Digital technology	Examples of application in the purchasing process
Analytics and big data	The application of big data serves to mitigate the potential for uncertainty in the decision-making process. It facilitates the real-time monitoring of the potential risk associated with a specific purchase, including the risk inherent in collaboration with cooperation with a supplier (Umbenhauer et al, 2017; Wyman, 2017). The analysis of both internal and external data obtained through the use of big data technology provides fact-based arguments that are useful in the context of negotiation process. The application of big data analytics facilitates the formulation of effective purchasing strategies by enabling the identification of market trends and potential shifts in the market landscape of prospective suppliers, as well as the prediction of potential risks (Gottge et al., 2020).
Cloud services	The findings of a survey conducted by INDICATOR in 2016 on a sample of 122 organisations corroborate the influence of cloud solutions on the activities of the purchasing process at the operational level. This is evidenced by a reduction in costs associated with by: reducing costs in terms of order fulfilment, complaint handling and returns (Nowicka, 2019).
Blockchain	The potential of utilising blockchain technology in the purchasing process is to automate activities pertaining to contract management through the deployment of "smart contract" functionality. Smart contracts are concluded and executed automatically, without the need for any external control. However, they are trusted by all parties within the blockchain. A smart contract is a sophisticated transaction protocol that provides real-time notification of the occurrence of a condition for the application of pertinent contractual provisions. Examples of such provisions include the application of a discount, the implementation of option rights related to the modification of contract validity periods, and the enforcement of contractual penalties. A prerequisite for the implementation of blockchain technology in the context of smart contracts is the standardisation of the relevant contractual documents. Similarly, activities pertaining to verification and authorisation can be transferred to other documents, such as regulations and procedures. Blockchain technology has the potential to enhance and reinforce the security of identity verification processes, such as those employed in the context of tender submissions or electronic auctions. Other applications of blockchain technology in the purchasing process include: the creation of supply chains (in which the provenance of products or the evolution of production processes can be confirmed), the confirmation of the identity of entities participating in the tendering process and the confirmation of the reliability of data (obtained from disparate sources). Furthermore, blockchain technology can also be utilised in the process of cargo flow and customs clearance. This is due to the fact that it enables the identification of the product's origin, thereby reducing the risk of fraud and counterfeiting (Govindan et al., 2024).
Robotics	The implementation of robotics has the effect of accelerating and streamlining the logistics process of receiving deliveries, which can be considered an activity at the operational level of the purchasing process. Furthermore, the introduction of robotics has the additional benefit of increasing the efficiency of warehouse operations (Jankowska & Łukasiak, 2017).

Tab. 1: Examples of using SMAC/BRAID technology in the purchasing process – Part 3

Digital technology	Examples of application in the purchasing process
Automation of knowledge work	The implementation of RPA technology ensures the high quality processing of data, eliminates the potential for errors due to the influence of the human factor, guarantees an immediate response, and frees employees from performing tedious, repetitive activities. When concentration decreases, the risk of making an error increases, which can result in the poor quality of data in IT systems. As a result, employees are able to dedicate their attention to more complex problems, reducing the time taken to execute orders, and avoiding the necessity to implement new IT tools. Automation occurs within existing systems such as purchasing platforms, ERP systems, thereby enhancing the quality and efficiency of operational processes. Furthermore, it enables the tracking of changes in regulations, for instance, those set out in the Public Procurement Act. In addition, it enables the conducting of audits, such as those pertaining to purchasing, and the verification of the accuracy of data entered into IT systems. RPA technology is responsible for maintaining work continuity and allows staff to be freed up to engage in creative activities. RPA is the most cost-effective and straightforward to implement of the automation technologies. It is applicable to tasks that are time-consuming, routine and information-intensive. It permits the attainment of relatively straightforward productivity gains. RPA technology can be employed in the purchasing process, it can be used to identify purchasing needs, support the purchase-to-pay process (from placing orders to settling invoices and payments), create and process documentation, search for data and information, facilitate internal reporting, perform data analysis, conduct testing, archive data, and detect errors (Martinek-Jaguszewska 2018). Additionally, RPA technology is utilised in the purchasing process to automate the sourcing process, encompassing the creation of an inquiry, supplier qualification, and the management of supplier relationship (Hartley & Sawaya, 2019). The authors Flechsig and Lasch (2021) corroborated the feasibility of utilising RPA technology in the process of monitoring the level of order fulfilment, data management, supervision and reservation of deliveries, KPI reporting, and the updating of e-catalogues. Furthermore, RPA technology can also be utilised used to analyse expenditure and construct a supplier risk map, in addition to providing support for the development of specifications, including technical requirements based on historical data derived from tenders. The deployment of artificial intelligence enables the categorisation of unstructured expenses, costs, contracts, supplier data in real time. Furthermore, the utilisation of machine learning algorithms: forecasting of demand, the prediction of the prices of supplies and services, the prediction of future sources of supply and the acquisition of data from files in PDF format with the support of OCR (optical character recognition) technology (Umbenhauer et al., 2017).
Internet-of-things	The internet of things (IoT) facilitates the automation of shipment tracking and the real-time flow of data and information, thereby enhancing transparency and enabling the prompt identification and response to any anomalies in the process. The internet of things facilitates the exchange of information between business partners (Gottge et al., 2020; Nowicka, 2019), and can also communicate demand, thereby initiating the creation of a supply order. Communication occurs at the machine-to-machine level (Osmonbekov & Johnston, 2018).

Tab. 1: Examples of using SMAC/BRAID technology in the purchasing process – Part 4

Digital technology	Examples of application in the purchasing process
Digital fabrication	The potential of digital fabrication technologies lies in the ability to rapidly prototype, which is an integral part of the process of obtaining sources of supply for production materials – direct materials (Umbenhauer et al., 2017). The effective management of the purchase of spare parts is enabled by digital fabrication (Schrauf & Berttram, 2016), while the positive impact on the management of the company's labour costs has been demonstrated by Lakhman et al. (2023).

Source: own (based on Dalton et al. (2024), Diba et al. (2019), Flechsig and Lasch (2021), Gottge et al. (2020), Govindan et al. (2024), Hartley and Sawaya (2019), Jankowska and Łukasiak (2017), Kulikowska (2023), Lakhman et al. (2023), Martinek-Jaguszewska (2018), Nowicka (2019), Osmonbekov and Johnston (2018), Schrauf and Berttram (2016), Umbenhauer et al. (2017), Wyman (2017))

From the perspective of the analysis of digital technology analysis, it can be concluded that organisations contemplating the utilisation of digital technologies should prioritise the assurance of the quality and security of their critical data and systems. An effective purchasing process will facilitate the implementation of SMAC/BRAID digital technologies, influencing the redesign of the purchasing process and its digital transformation (Bals et al., 2019).

1.3 Mechanisms supporting and inhibiting digital transformation of the purchasing process

The potential for successful digital transformation and effective process digitalisation in an organisation is largely dependent on a number of organisational factors, including the existence of a strategy and vision, the quality of leadership and governance, and the efficacy of management (Światowiec-Szczepańska & Stępień, 2022; THINKTANK, 2023). Many companies lack a clear digital transformation strategy, a solid technology infrastructure, and the full commitment of top management. Additionally, they are discouraged by the high expenditure required to build skills and acquire technology (Dubey et al., 2020; Helo & Hao, 2021). Conversely, organisational factors have a bearing on the other two groups of drivers of digital transformation and process digitalisation, including social factors, which include employees and their competencies (Flechsig & Lasch, 2021) and organisational culture (THINKTANK, 2023). Furthermore, technological factors, which include data, and IT infrastructure (Köppel et al., 2021). In addition, the level of digital adoption (McKinsey, 2018) and the aforementioned factors must be considered.

The application of business process digitalisation tools is not merely a matter of mapping existing processes to their digital equivalents. Rather, it entails a fundamental rethinking of existing processes from perspective of the possibilities offered by digital technologies (Parviainen et al., 2017). The purchasing process digitalisation is contingent upon the present of the requisite conditions, otherwise the endeavour is doomed to failures. Such conditions pertain to implementation barriers, this is to say, they constraints inherent to a given implementation to which an organisation is exposed.

The critical factors identified in the literature that inhibit the digital transformation of business processes, including the purchasing process, can be classified into three dimensions: organisational, social, and technological. The social factor that most impedes digital transformation of organisations is people's resistance to change or their resistance to change per se Flechsig and Lasch (2021) and Światowiec-Szczepańska and Stępień (2022). It is an inherent characteristic of change that it engenders a certain degree of anxiety. The advent of digital transformation gives rise to a certain degree of anxiety among employees, who may be uncertain about their ability to function effectively in this novel environment or possess the requisite competencies (Leonardi & Neeley, 2022). As Rejeb et al. (2018) observe, individuals tend to resist change because they are reluctant to abandon established work routines and to adapt to existing IT systems.

In order for digital transformation to be achieved, it is essential that the fundamental components or the organisation are aligned

and coordinated. The organisational culture, leadership, and the organisation's vision and strategy from a digitalisation perspective will be aligned if they are digitalized. This is corroborated by the evidence that the organizational factors identified by researchers as hindering digital transformation are: a lack of a defined vision and strategy for digitalisation (Flechsig & Lasch, 2021; Światowiec-Szczepańska & Stępień, 2022), a lack of digital organisational culture (Flechsig & Lasch, 2021; Kane et al., 2019) and a lack of digital leadership (Flechsig & Lasch, 2021; Kane et al., 2019; Światowiec-Szczepańska & Stępień, 2022). In addition to the aforementioned organisational barriers to the digital transformation of organisations, researchers have identified a lack of budget or insufficient budget as a financial or economic barrier for organisations (Flechsig & Lasch, 2021; Światowiec-Szczepańska & Stępień, 2022).

From a technological standpoint, the primary impediments to the digitalisation of business processes are the data barrier and the necessity for an adequate IT infrastructure. As algorithms embedded in digital technologies interact with data, ensuring the quality and consistency of that data is of paramount importance for the successful digital transformation of processes (Flechsig & Lasch, 2021). Inadequate data quality increases the probability of erroneous decisions and significant organisational losses (Wieczorkowski & Jurczyk-Bunkowska, 2018). The IT and OT infrastructure of the energy sector is increasingly vulnerable to cyber-attacks, given its status as a critical component of national infrastructure (Nazari & Musilek, 2023). Consequently, ensuring the security of systems, devices, and data has become a top priority for energy companies (Flechsig & Lasch, 2021; Nazari & Musilek, 2023; Wallenburg et al., 2020). Thus, another technological obstacle to digital transformation is the threat of cyber-attacks (Bienhaus & Haddud, 2018). Inadequate preparation of employees for cyber threats can exacerbate their resistance to digital change, resulting in limited confidence in data security. Another technological barrier identified in the literature is the presence of an outdated IT infrastructure that is not compatible with new technologies (Flechsig & Lasch, 2021; Światowiec-Szczepańska & Stępień, 2022).

2. Methodology

The stated research objective, namely to identify the mechanisms that support and hinder the digital transformation of the purchasing process in energy companies in Poland, was achieved through the implementation of a qualitative research approach, based on a case study comprising eleven expert interviews. The appropriateness of the selected research method is substantiated by the fact that the phenomenon under investigation is not yet fully defined and challenging to distinguish from the context in which it manifests (Yin, 2015). This is undoubtedly the digital transformation of the purchasing process in the energy sector (Shumon et al., 2019) and the mechanisms that support and inhibit it. The selection of respondents was purposive, which is consistent with the assumptions underlying the conduct of expert interviews (Stempień & Rostocki, 2013; Yin, 2009). This implies that the interviewee is a subject matter expert with extensive knowledge of the field.

Three criteria were employed in the selection of the research sample from the knowledge and experience category. These included a minimum of eight years of professional experience in purchasing as a manager and a minimum of eight years of professional experience in the Polish energy company and any experience in the implementation of digital initiatives in the purchasing process. Semi-structured face-to-face expert interviews were conducted with 11 purchasing managers from eight Polish energy companies. The decision to cease conducting interviews was informed by the emergence of recurrent categories, a phenomenon known as a category saturation (Suddaby, 2006). The last three interviewees did not present any new categories of implementation barriers. In the majority of cases (i.e., 10) the interviews were conducted online using the MS TEAMS application between January and February 2024. The average duration of an interview was 1 hour and 22 minutes, the average tenure of the research sample in the purchasing area was fifteen years, and the average tenure of the research sample in the energy sector was twenty years. Tab. 2 presents the demographic characteristics of the interviewees and basic interview data.

In order to facilitate the interviews with the targeted managers in an efficient manner, a presentation was prepared and distributed to them at the stage of inviting them to the research. This presentation explained the rationale for the interviews and the meaning

Tab. 2: Interviews with purchasing managers in Polish energy companies

Type of interview	Duration of interview (hod:min)	Number of employees working in purchasing dept.	Position	Experience in purchasing (years)	Experience in energy sector (years)	Experience in digital initiatives implementation (yes/no)
Online	01:19	5/250	Lower level management	12	15	Yes
Online	01:15	6/250	Lower level management	11	17	Yes
Online	00:35	100/250	Senior management	10	15	Yes
Online	01:40	50/250	Lower level management	36	41	Yes
Online	01:51	50/250	Lower level management	20	16	Yes
Online	01:54	17/250	Lower level management	11	15	Yes
Online	00:57	8/250	Lower level management	10	20	Yes
Online	01:19	17/250	Lower level management	8	8	Yes
Writing	01:00	50/250	Senior management	10	31	Yes
Online	01:15	25/150	Senior management	22	23	Yes
Online	01:57	5/250	Senior management	17	23	Yes

Source: own

of the definitions of the terms used in the questions, as well as provided a list of questions that was prepared and sent to them at the stage of inviting them to the research. This allowed the managers to become acquainted with the topics to be discussed during the interviews in advance, thereby facilitating their preparation and ultimately ensuring the interviews were conducted in an efficient manner. The number of participants in the study (i.e., eleven managers) is sufficient for the purposes of exploratory research, as recommended Keränen and Jalkala (2013).

The interview questionnaire, which formed part of a wider study, included questions on the demographic variables of the participants, the digital maturity of the entire organisation, and the degree and vision of digitalisation, automation, and integration of the purchasing process in a Polish energy company. This paper presents an analysis of the interview data on the digital maturity of the surveyed energy companies.

Upon completion of the interviews, the audio files were transcribed. Subsequently, the transcript was subjected to a rigorous examination for accuracy, and any necessary corrections were implemented. A qualitative content analysis was conducted on the individual interviews. This method entails a meticulous reading and interpretation of data in order to identify and delineate themes or segments comprising analogous material. This entails the establishment of expansive and subjective coding categories (Czernek, 2020; Morgan, 1993). The interview material on the digital maturity of energy companies was subjected to two levels of categorization. At the initial level of analysis, the following categories were employed: leadership, digital organisational culture, digital skills, digital change management, data governance/data-driven processes,

digitalisation vision and strategy, and barriers to implementation. At the second level, the following categories were used to identify barriers to implementation: data barrier, lack of digital leadership, excessive bureaucracy and controls, lack of budget, human resistance, the barrier of time and human resources constraints, lack of digital skills, lack of vision for digitalisation, lack of full understanding of the purchasing process on the part of those responsible for implementing the digital initiative, and technical barriers related to security requirements for the energy sector.

3. Results and discussion

A factor analysis of the survey results and coding of the responses identified ten factors inhibiting the digital transformation of the purchasing process in energy companies (Appendix).

The respondents identified the following factors as impeding the digital transformation process of the energy company's purchasing area: human resistance (10 out of 11 responses), lack of budget (7 out of 11 responses), time and human resources barrier (4 out of 11 responses), lack of digital leadership (3 out of 11 responses), data barrier (3 out of 11 responses). Two respondents identified excessive bureaucracy and excessive controls as factors impeding digital transformation. One respondent each identified a lack of digital skills, a lack of vision for digitalisation, and a lack of full understanding of the purchasing process on the part of those responsible for implementing the digital initiative as factors impeding digital transformation. One respondent identified technical barriers related to security requirements for the energy sector as a factor impeding digital transformation. The majority of the factors identified by respondents as impeding the digital transformation process can be classified as organisational in nature. This includes factors such as a lack of budget, time and human resources, a lack of digital leadership, excessive bureaucracy and control, and a lack of vision for digitalisation can be categorized as organisational in nature. In contrast, the factors related to the technological dimension were the least frequently mentioned, namely data barriers and technical barriers linked to security requirements for the energy sector. The resistance and lack of competence exhibited by individuals can be considered social factors (factors with a social dimension). The lack of full understanding of the purchasing process by those responsible for implementing digital solutions represents a factor that straddles the organisational and social dimensions.

The factor most frequently identified by respondents as an obstacle to the implementation of the digitalisation of business processes and the digital transformation of energy companies was found to be people's resistance. The importance of this factor and the high frequency of its occurrence have already been pointed out by previous studies (Flechsig & Lasch, 2021; Rejeb et al., 2018; Światowiec-Szczepańska & Stępień, 2022). The respondents' statements on human resistance to the implementation of the digitalisation of the purchasing process point to various sources of this resistance to change; including lack of a clear vision and strategy, lack of support from superiors, the unfamiliarity with the process on the part of those implementing the transformation processes, as indicated by the respondents' statements below (R – respondent).

"Resistance from the employees involved in the process. People are afraid that it will be to their disadvantage, that they will not be needed, that the system will replace them." (R1)

"There will always be an employee who is "no" and only becomes convinced of a particular digital initiative after implementation." (R2)

"Every time a digital initiative was implemented, there was human resistance at the beginning. People involved in the asked questions: What for, and who needs it? We do not need to use it." (R4)

"Process participants involved in using digital change do not feel a vision for change at the beginning because they do not want change; if something works as it is, it is enough for them because they can navigate it, they are afraid if they can manage it, lack of readiness and willingness to change on the part of people." (R7)

"There is always the question: And why? there is an initial reluctance to change. We do not have a choice; when something is implemented, we accept it for implementation." (R8)

"Lack of vision for digitalisation." (R9)

"When another system is implemented, there is resistance. There is a lack of communication. Why change to an inferior system when there is the prospect of implementing a better system in the near future." (R12)

As evidenced by the respondents' statements presented above, another source of people's resistance to the digital transformation of the purchasing process can be attributed to the lack of clarity surrounding the benefits and limitations of the implemented change (R1, R4, R8). Subsequently, the absence of a digital organisational culture, encompassing a transformation of mindset, was identified as a contributing factor to resistance.

"There will always be an employee who is "no" and only becomes convinced of a particular digital initiative after implementation." (R2)

"There are mainly mental barriers among employees." (R10)

Conversely, the absence of established cybersecurity standards and norms gives rise to concerns about the potential loss of control over the process, as highlighted by respondent 1 (R1) in their statement.

"Resistance is triggered by fear of cyberattacks and negative experiences with digital systems, their functioning or their operational stability (...) and the fear of data loss." (R1)

The reasons for resistance to the digital transformation of the purchasing process in the energy sector, as identified by the respondents may give rise to dysfunctional phenomena within the organisation. If these phenomena persist, they may result in the emergence of organisational pathologies, which could ultimately lead to permanent organisational inefficiency, mismanagement, and waste both in terms of economic resources and potential gains from digitalisation (Młody, 2019).

The primary factor impeding human adaptation to digital transformation is the lack of organisational preparedness for such a transition (Flechsig & Lasch, 2021; Światowiec-Szczepańska & Stępień, 2022; Xu et al., 2021). The assertion is corroborated by the findings of our study. The organisational dimension revealed that respondents identified three key barriers: a lack of budget, a lack of time and a shortage of staff.

"The main barrier is cost. If implementing a digital initiative requires a financial commitment, then there have been situations where implementation has been suspended." (R4)

"More functionality could be implemented for digital initiatives, but funding for this is lacking." (R5)

"A great deal of digital change can still be implemented in the purchasing process; it is only a question of the availability of two resources: time and money." (R7)

"Budget is always a barrier. We limit ourselves to a smaller implementation and are open to further application/system development. Rarely do we back out entirely." (R11)

"There are financial constraints; we cannot afford everything." (R12)

"Preparation, procedure, and training require a time resource in short supply." (R5)

"If time and human resources have to be diverted to other more important tasks, then implementing a digital initiative is not possible; we experienced this recently with the priority of unbundling coal assets." (R11)

"Due to the limited number of FTEs, there is not enough time to implement or train in using new digital tools. The priority is to maintain business continuity." (R12)

The implementation of digital initiatives is associated with the purchase of new IT infrastructure or the development of existing infrastructure, as well as the cost of qualifying specialists or acquiring qualified specialists from the market (Wieczorkowski & Jurczyk-Bunkowska, 2018). In order to invest in digital initiatives it is necessary to plan and secure a specific budget within the material and financial plan.

The respondents indicated that digital transformation is unfeasible or significantly impeded in the energy companies they represent due to the absence of digital leadership. Consequently, the digital organisational culture and essential organisational components and procedures lack coherence and coordination, as evidenced by the following statements of the respondents.

"Lack of management support." (R1)

"The head office purchasing director should promote and support the implementation of digital initiatives. So far, he is holding back." (R2)

"The board will not perform activities in a dedicated IT system. The board office works on paper; specifications are printed, and there is no willingness to digitize in terms of resolutions and orders; hence, there is no translation to other business processes in terms of digitalization. (...) Lack of example from the top in terms of digitalization of the process, if the board office were to procedure activities digitally, it would be easier to implement digitalization in other business processes." (R9)

"It took a very long time to decide on the deployment of cloud tools; the security area

advised against deployments and applied such strictures in this regard that valuations of a solution were unattainable." (R11)

The alignment of organisational culture, leadership, and the organization's vision and strategy in terms of the purchasing process transformation perspective will be achieved when the aforementioned elements are are digital. This is also corroborated by the findings of Kane et al. (2019) and Flechsig and Lasch (2021), which indicate the necessity for a clear vision and strategy for digitalisation, digital culture, and digital leadership as organisational factors that impede the digital transformation of business.

The respondents indicated that the implementation of digital technologies alone does not guarantee the desired outcomes of digitalisation. Consequently, there is minimal emphasis on the expeditious integration digital technologies including cloud computing, machine learning, blockchain, and robotic process automation (RPA), within the energy sector companies. The adoption of digital technologies in isolation does not present a significant obstacle. The respondents identified data barriers as the primary technology-related impediments to business process digitalisation.

"Today, the system is powered by human actions, and unintentional mistakes can happen. An upgrade of the ERP system is planned, where the implementation concept assumes validators and monitors in the system to take care ultimately of the quality of the data recorded so that in the future, we can implement data-driven digital technologies so that there are no data barriers." (R5)

"Lack of attention to hygiene and data quality. What is the use of you will have the best washing machine on the market if you put the worst powder in it." (R9)

The quality and consistency of data are of paramount importance in the digital transformation process, as the algorithms embedded in digital technologies interact with data from a technological perspective. This is corroborated by the findings of the analysis of Flechsig and Lasch (2021). On the other hand, Nazari and Musilek (2023) note that the majority of energy companies contend with the challenge of suboptimal data quality and disparate data sources, which represent a significant technological impediment to the digitalisation of business processes. Inadequate data quality heightens the probability of erroneous decision-making and renders the organisation vulnerable to substantial losses.

The analysis of the data collected during the interviews and based on K. Lewin's theory, has led the authors propose five mechanisms to support the digital transformation of the business processes in energy companies, with the purchasing process serving as an illustrative example. Given that the majority of obstacles to digital transformation in the purchasing process of an energy company are of a socio-organisational nature, it is imperative that energy companies undergo organisational change. In the light of K. Lewin's theory, the objective of organisational change is firstly to eliminate or diminish the inhibiting factors intrinsic to the organisation, and subsequently to reinforce the factors that facilitate a specific change (Błaszczyk, 2005). The proposed mechanisms 1–4 are designed to minimize human resistance and comprise to the implementation of a digital change management process, the implementation of a digital vision and strategy, the development of digital competencies and the introduction of digital leadership. The fifth mechanism, which pertains to the data barrier and concerns the implementation of a data infrastructure management standard.

The first mechanism is the implementation of a digital change management process. The objective of managing the change resulting from the implementation of digital initiatives and, in particular, the implementation of digital transformation, is to eliminate employee resistance to change (Cichosz et al., 2020; Światowiec-Szczepańska & Stępień, 2022) and increase employee engagement in the digital transformation process. The first step is to prepare employees for the forthcoming digital change, which is then followed by the implementation of a digital change management standard. In order to assist with the preparation of employees for the changes that arise from digital transformation, a tool proposed by Leonardi and Neeley (2022) – the employee response matrix for digital transformation (Fig. 3) – can be utilised. The matrix facilitates the identification of the position of employees in the organisational digital transformation process. It is desirable for employees to be situated in the upper right-hand quadrant of the matrix, indicating that they are inspired by the change, believe they can learn new things, acquire new skills and look forward to the transformation.

As posited by the authors of the matrix, the objective of motivating employees to acquire digital competence is to move them out of the zone of feeling overwhelmed or indifferent and into the zone of feeling inspired. This can be achieved by increasing support and acceptance of the forthcoming changes, thereby motivating employees to embrace digital transformation. In order to effectively manage digital change, it is essential to implement key actions. Firstly, it is vital to increase the intensity of messages from senior management that emphasise

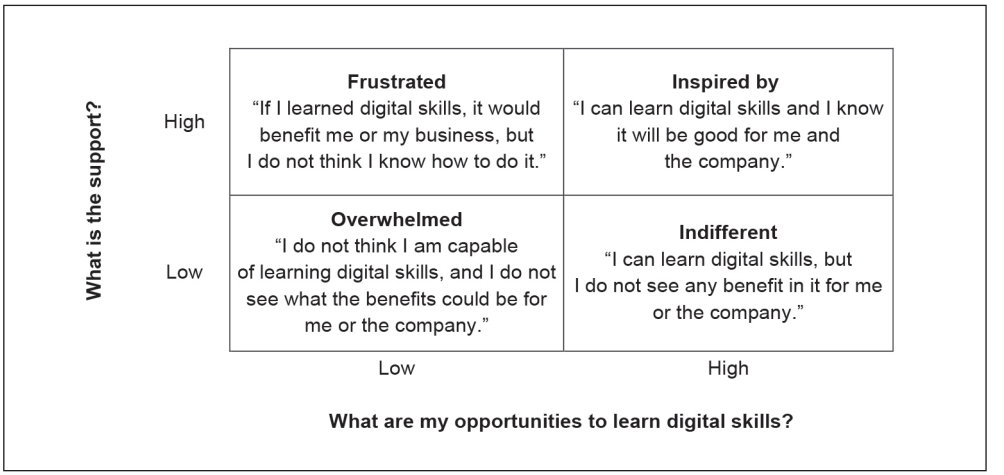

Fig. 3: Employee response matrix to digital transformation

Source: Leonardi and Neeley (2022)

the importance of digital transformation as a new strategic direction. Secondly, an internal marketing campaign should be initiated to create a positive image of the organisation supported by digital technologies. Thirdly, employees must be motivated to see themselves as contributing participants in the digital organisation. In order to effectively manage digital change in an energy company, it is essential to implement a standard based on one of the project management methodologies. Among these, agile methodologies are particularly well-suited to the context of digital transformation.

The second mechanism is the implementation of a digitalisation vision and strategy, i.e., a clear digital transformation plan. A digitalisation strategy outlines the extent of digital transformation, delineating the processes to be automated and integrated, classifying the digital initiatives to be implemented, and establishing the framework and standards for their implementation in a manner that achieves the organisation's strategic goals. It is essential that the digital vision and strategy promote a digital organisational culture that is aligned with the company's overarching vision, mission, and strategy. Organisational culture defines the manner in which a company operates and implements change, and is based on a set of norms, values, and attitudes that are clearly communicated and shared by all stakeholders (Cichosz et al., 2020). A digital organisational culture is defined by a set of values and attitudes that encourage innovation, experimentation, risk-taking, openness to change, customer focus, open communication and information sharing, a focus on agility over control, and an organisational atmosphere that supports ingenuity, creativity and an entrepreneurial approach. A digital organisation should be data-driven, which entails a transformation of the organisational culture to align decision-making processes with data-driven principles and facts, rather than relying on experience and intuition as was the case in the past (Capgemini, 2017; McAfee & Brynjolfsson, 2012).

The third mechanism is the development of digital skills. The term "digital competencies" encompasses a range of skills, including information and data literacy, communication and collaboration, media literacy, digital content creation (including programming), security (including digital comfort and cybersecurity competencies), intellectual property issues, problem solving, and critical thinking (DigComp 2.2, 2022). In practice, however, the digital literacy of employees in all strategic areas of an organisation represents a significant challenge. A case study of companies that have successfully implemented employee training to increase the digital literacy of their workforce identified six effective practices (Leonardi & Neeley, 2022). These are as follows: firstly, setting a training target for the entire organisation; secondly, developing training opportunities that include all positions; thirdly, prioritising a virtual training method so that learning is scalable and universally accessible; fourthly, motivating people to learn through campaigns, nominations, and awards; fifthly, providing digital training to managers so that they understand the offering and motivate employees; and finally supporting projects within the company that introduce digital components that lead to direct applications.

The fourth mechanism is the introduction of digital leadership. The implementation of digital organisational change requires the presence of digital leadership, which, according to Burnes (2004), requires leaders to act in three fundamental ways: firstly, by establishing a vision of digitalisation and involving organisational participants in its realization; secondly, by shaping a digital organisational culture that is conducive to change and continuous performance improvement, and thirdly, by developing new organisational solutions and procedures for change participants to follow in the new digital environment. The promotion and active utilisation of digital solutions by managers can facilitate a positive impact on organisational digital transformation (Rosenberger et al., 2021). This can be achieved through the continuous monitoring of market trends in digital solutions, coupled with a comprehensive understanding of these trends and the capacity to translate technological opportunities into business strategies (Cichosz et al., 2020; Zhang et al., 2022). The information and communication technology (ICT) sector is at the vanguard of digital transformation (OECD, 2024). According to Rueckel et al. (2020), companies that are committed to digital transformation should contemplate modifying their organisational structure by appointing new roles tasked with overseeing digital transformation, such as a chief digital officer (CDO) or a chief information officer (CIO). As emphasized by Wieczorkowski and Jurczyk-Bunkowska (2018), there is a need for appropriate management focused on systemic breakthroughs and minimising the risk of their negative impact.

The fifth mechanism is the implementation of a data infrastructure management standard. The 2023 Data Economy Conference, entitled "Preparing the energy company for processes digitalization," adopted the theme of data as the fuel for energy transformation as its keynote topic. From a societal perspective, digital organisational culture is data-driven; from an organisational perspective, a digital leader should base their decisions based on data and facts rather than experience and intuition. From a technological perspective, the key objective is to identify the most appropriate technological solutions. Firstly, the integration of data and the establishment of a unified database are or significant importance (Köppel et al., 2021; Leyh & Meischner, 2018). The integration of data integration within IT systems will facilitate the exploitation and transformation of data into valuable information, which can then inform business decisions. Secondly, the access to both internal and external data is required, and a standardised process for data collection, storage, and analysis must be established (Bienhaus & Haddud, 2018; Köppel et al., 2021; Wieczorkowski & Jurczyk-Bunkowska, 2018). Thirdly, researchers highlight the significance of data security security (Köppel et al., 2021) and quality in systems (Wieczorkowski & Jurczyk-Bunkowska, 2018). It is imperative to implement robust cybersecurity procedures and solutions to ensure the integrity and accuracy of data stored in IT systems.

Conclusions

The findings of the research, together with their subsequent analysis, enabled the identification of ten factors that are impeding the digital transformation of the purchasing process in energy companies in Poland. Furthermore, the article also puts forth five recommendations for potential mechanisms that could assist

in overcoming identified barriers to the transformation of the purchasing process.

This study highlights the importance of effective digital change management, a comprehensive vision and strategy for business digitalisation, the development of digital skills among employees, and the implementation of robust data infrastructure management practices in the digital transformation of the purchasing process. The implementation of mechanisms that support the digital transformation of business processes is the sole means of unlocking the digital potential of energy companies in Poland. It is currently estimated that energy companies in Poland still require effective digital transformation readiness. As Shaw (2020) asserts, advancement is contingent upon transformation. The implementation of organisational change is a prerequisite for digital progress in energy companies in Poland, progress is only possible with change. Digital progress in energy companies in Poland requires the implementation of organisational change. The key to success in the digital transformation of business processes is the appropriate involvement of employees and management at every stage of the process.

The research findings allow for the proposition that managers or energy companies should be encouraged to pursue a path of transformation in their purchasing processes. This should be done in a considered manner, with due attention paid to the identification of mechanisms that can facilitate the implementation of these changes in a manner that is both evolutionary and effective.

It is not possible to effect positive change in the technological maturity of the energy sector without first identifying and implementing mechanisms that support digital transformation. Moreover, the identification and elimination of impediments to the digital transformation of purchasing processes in the energy sector will facilitate the implementation of mechanisms that support the transition towards modernity.

Limitations. It should be noted that this exploratory study is subject to a number of limitations. The study was conducted on a limited sample of eight Polish energy companies. The surveyed companies are part of large capital groups with a centralized structure, which is consistent with the nature of the energy sector. The purchasing process in the surveyed companies is conducted via IT systems, including a purchasing platform and an ERP system. Process management is also implemented at the organisational level. Therefore, extreme caution should be exercised when attempting to generalize the results of this study to companies operating outside the energy sector. Further research could examine the potential for benchmarking energy companies with entities that have undergone digital transformation, for instance, from the banking sector. It would be beneficial to conduct a comparative analysis of analogous cases of digitalisation of purchasing processes in other countries or sectors in order to enhance the research.

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Appendix

Tab. A1: Barriers to the purchasing digital transformation process in an energy company with the assigned responses of the respondents – Part 1

Type of barrier (second-order code)	Respondent's reply (example of evidence)
Human resistance	"Resistance from management." (R1)
	"Fear-induced resistance to cyber-attack." (R1)
	"Negative experiences with digital systems, their functioning or their stability of operation." (R1)
	"Resistance from the employees involved in the process. People are afraid that it will be to their disadvantage, that they will not be needed, that the system will replace them." (R1)
	"There will always be an employee who is "no" and only becomes convinced of a particular digital initiative after implementation." (R2)
	"I observe resistance among employees who are overloaded with work and lack desire and passion. There are also employees who, due to past experiences of work reorganisation or job demotion, have influenced a reduced willingness to implement initiatives of any kind." (R3)
	"For every implementation of a digital initiative, human resistance was encountered at the beginning. Participants in the process were asking questions: What for, and who needs it, we do not need to use it." (R4)
	"There are people of varying ages, IT sophistication among managers and if the implementation of a digital initiative required adaptation to change, there were times when the person or their area would not benefit from the digital initiative implemented." (R4)
	"Process participants involved in using digital change do not feel a vision for change at the beginning because they do not want change, if something is working as it is, that is enough for them because they can navigate it, they are afraid if they can manage it, there is a lack of readiness and willingness to change on the part of people." (R7)
	"The quality of people's work, the attachment to what is and the lack of verve and willingness to change, the reluctance to change, the attachment to paper." (R9)
	"There are mainly mental barriers among employees." (R10)
	"There is always the question: And why?, there is an initial reluctance to change. We do not have a choice, when something is implemented we accept it for implementation." (R8)
	"Purchasing HQ is a pioneer in digital implementations, however, because it acts as a shared service centre and not as a parent company, this does not have a significant impact on the extent of implementation in the other group companies. For example, digital signatures were implemented in the purchasing CUW earlier, purchasing was at the ready, and other companies in the organisation only used prepared solutions including regulation when there was a pandemic." (R11)
	"When another system is implemented, there is resistance. There is a lack of communication, why to change an inferior system, when there is the prospect of implementing a better system in the near future." (R12)

Tab. A1: Barriers to the purchasing digital transformation process in an energy company with the assigned responses of the respondents – Part 2

Type of barrier (second-order code)	Respondent's reply (example of evidence)
Lack of budget	"Cost is a barrier." (R2) "The main barrier is cost. If the implementation of a digital initiative requires financial commitment, then there have been situations where implementation has been suspended." (R4) "More functionality could be implemented for digital initiatives, but funding for this is lacking." (R5) "A great deal of digital change can still be implemented in the purchasing process, it is only a question of the availability of two resources: time and money." (R7) "Yes, mainly budgetary, mental and the inability of IT services to meet expectations. That is, what we would like to do cannot always be done." (R10) "Budget is always a barrier. As a rule, we limit ourselves to a smaller implementation and are open to further application/system development. Rarely do we back out entirely." (R11) "There are financial constraints, we cannot afford everything." (R12)
Barrier of time and human resources	"Preparation, procedure and training requires a time resource that is in short supply." (R5) "A great deal of digital change can still be implemented in the purchasing process, it is only a question of the availability of two resources: time and money." (R7) "If time and human resources have to be diverted to other more important tasks, then the implementation of a digital initiative is not possible, we experienced this recently with the priority of unbundling coal assets." (R11) "There are limitations in terms of statecraft." (R12) "Due to the limited number of FTEs, there is not enough time to implement or train in the use of new digital tools. The priority is to maintain business continuity." (R12)
Lack of digital leadership	"Lack of management support." (R1) "The director of purchasing from head office should promote and support the implementation of digital initiatives. So far, he is holding back." (R2) "The board will not perform activities in a dedicated IT system. The board office works on paper, specifications are printed, no desire to digitise in terms of resolutions, orders, hence no translation to other business processes in terms of digitisation." (R9) "There is a lack of example from the top in terms of digitising the process, if the management office were to procedure activities digitally then it would be easier to implement digitisation in other business processes." (R9)

Tab. A1: Barriers to the purchasing digital transformation process in an energy company with the assigned responses of the respondents – Part 3

Type of barrier (second-order code)	Respondent's reply (example of evidence)
Data barrier	"There is a concern about data loss." (R1) "Today, the system is powered by human actions and unintentional mistakes can happen. An upgrade of the ERP system is planned, where the implementation concept assumes validators and monitors in the system to take care of the quality of the recorded data ultimately, so that in the future we can implement data-driven digital technologies so that there is no data barrier." (R5) "Lack of attention to hygiene and data quality. What is the use of "You will have the best washing machine on the market if you put the worst powder in it?"." (R9)
Excessive bureaucracy and excessive controls	"Recommendations after an internal control or audit conducted inhibit the implementation of digital initiatives." (R2) "Bureaucracy of board members in other group companies." (R2) "Excessive control and forced entry of additional information in the system relevant only to internal audit." (R2 observed at another group company) "The implementation of a digital initiative can take as long as the approval procedure itself for that digital initiative, there is excessive bureaucracy and "papirology," which demotivates people to come up with further ideas." (R7)
Lack of digital competence	"Due to the lack of digital maturity of employees, electronic signatures are not used everywhere in practice, digital signatures are not worked in a ready-made digital environment, and there are no acceptance paths in the system for managers." (R7)
No vision for digitalisation	"Lack of vision for digitalisation." (R9)
Lack of full understanding of the purchasing process on the part of those responsible for implementing the digital initiative	"Lack of experience in the purchasing process, e.g., related to the reverse procedure in a tender procedure with staff at Head Office, then the digital initiative implemented may be poorly implemented, not anticipating all scenarios, which may result in a longer procedure time." (R2)
Technical barrier related to security requirements for the energy sector	"It took a very long time to decide on the deployment of cloud tools, the security area advised against deployments and applied such strictures in this regard that valuations of a solution were unattainable." (R11)

Source: own

How does top management's environmental awareness influence green innovation: The moderating role of absorptive capacity and slack resources

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Abstract: *Based on the upper echelons theory, dynamic capability theory, and resource-based view, this study explores the impact of top management's environmental awareness (TMEA) on green innovation (GI), the moderating role of absorptive capacity (AC) and slack resources (SR). Using the data of A-shared listed manufacturing firms in China from 2010–2023, this study finds that TMEA has a significant positive effect on GI. Furthermore, AC and unabsorbed slack resources (USR) strengthen the effect of TMEA on GI, whereas absorbed slack resources (ASR) weaken the effect of TMEA on GI. The results provide a more comprehensive understanding for enterprises to implement GI, expand boundary conditions between TMEA and GI, and contribute to the improvement of research on GI.*

Keywords: *Top management's environmental awareness, green innovation, absorptive capacity, unabsorbed slack resources, absorbed slack resources.*

JEL Classification: *M140.*

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Introduction

With the deterioration of global environmental problems, China announced the goals of "peak carbon dioxide emissions" and "carbon-neutral" to the world, giving unprecedented attention to green innovation (GI). GI refers to the innovation aimed at reducing the impact on the environment in the process of enterprise operation, including energy saving, pollution prevention, waste recycling, green product design, and enterprise environmental management technology (Chen et al., 2006). GI cannot only promote enterprises to speed up the transformation of production mode, but also promotes the manufacturing industry to effectively control pollution and rationally use resources (Li & Lu, 2022). In addition, through GI, the reputation of enterprises is improved due to the spillover

effect, thus increasing the demand for enterprise products (Eiadat et al., 2008). Although GI is an economic behavior centered on improving environmental performance, it has the characteristics of high risk, high input and external duality, which leads to the phenomenon that the company's GI motivation is insufficient (Xing & Yu, 2019). Therefore, it is of great theoretical and practical significance to explore the driving factors of GI in enterprises.

As for the research on the driving factors of GI in enterprises, most scholars have studied the influence of external driving factors, such as environmental regulation, financial subsidies and environmental pressure of stakeholders on GI (Hojnik et al., 2016; Porter et al., 1999; Xie et al., 2020). However, the above research cannot explain the performance differences of GI of different enterprises in the same external environment, so scholars began to focus on the internal driving factors of enterprises, such as enterprise scale, R&D level and executive characteristics, which will affect enterprises' GI (Liao & Cheng, 2014). Especially the top managers who are the strategists and resource allocators of enterprises, their understanding of the environment plays a decisive role in GI. Top management's environmental awareness (TMEA) is their perception of environmental protection and sustainable development based on their personal knowledge structure and values (Xing & Yu, 2020). According to the upper echelons theory, managers with environmental awareness can eliminate obstacles in the process of GI (Hambrick, 2007), promote enterprises to carry out green product innovation and enhance their green competitive advantage (Cao et al., 2021; El-Kassar & Singh, 2019; Patrick, 2019).

Although these studies are helpful for us to understand the driving factors of GI, there are still some shortcomings in existing studies. First, most studies focus on the influence of external driving factors such as environmental regulations and government subsidies on GI, relatively few studies have investigated the internal driving factors. However, whether an enterprise can carry out GI ultimately depends on its own cognition and strength, especially on top management's cognition and interpretation of environmental policies. Therefore, TMEA determines the strategic choice of the enterprise and is an important determinant of GI. However, the research on how TMEA affects enterprises' GI is not sufficient. Second, there is a lack of discussion on boundary conditions of how TMEA affects GI from the perspective of internal resources and capabilities of organizations. Although GI of enterprises is supported by external resources such as financial subsidies, what is more important is that the internal resources and capabilities are owned by enterprises themselves. If the internal resources and capabilities are insufficient, the effect of market demand and environmental regulations on GI will not be obvious (Zailani et al., 2015). Therefore, organizational resources and capabilities may also affect the relationship between TMEA and GI.

Based on upper echelons theory, resource-based view and dynamic capability theory, this study explores how TMEA affects GI, and finds that slack resources (SR) and absorptive capacity (AC) are moderating variables in the relationship between TMEA and GI in order to contribute to GI theory.

1. Theoretical analysis and hypotheses development

1.1 Top management's environmental awareness and green innovation

Top managers' in-depth understanding of environmental risks and benefits enables them to pay more attention to environmental issues, thus discovering more business opportunities and responding more quickly and actively by implementing environmental solutions such as GI activities. Because GI has the characteristics of high risk, high investment and long payback period, enterprises lack the priority in allocating resources to GI. However, executives have the right to control enterprise resources, and their willingness to use organizational resources for GI often depends on their understanding of environmental protection. Managers' perceptions will guide the subsequent strategic choices and actions (Kaplan, 2011), which will further affect the development of GI. The stronger the environmental awareness, the more executives can discover the potential benefits and opportunities in the market, so as to allocate the resources and capabilities within the enterprise more reasonably. In the literature, TMEA can be divided into general awareness and environmental awareness. General awareness refers to the top management's understanding of the company's environmental impact,

environmental measures and environmental practice. Out of a sense of social responsibility, senior executives aim to reduce the negative impact on the environment through GI. Environmental awareness refers to the top manager's awareness that GI can reduce costs, increase income and improve environmental performance (Gadenne et al., 2009).

Executives with strong environmental awareness can identify the green resources or needs of stakeholders, put resources into GI, and actively allocate enterprise resources to make the production and operation of enterprises green, thus meeting the existing green needs in the market. Managers should also realize the importance of GI in dealing with environmental risks, building environmental capacity and creating first-mover advantages (Peng & Liu, 2016). These advantages are lasting and difficult to imitate, which gives enterprises a priority in the competition and contributes to the long-term development of enterprises. Therefore, TMEA will stimulate the green process innovation and green product innovation of enterprises. Therefore, the following hypothesis is proposed:

H1: TMEA positively influences GI.

1.2 Moderating role of absorptive capacity

According to the dynamic capability theory, enterprises need to continuously establish, reorganize and allocate internal and external resources in order to achieve competitive advantage (Teece, 2007). Cohen and Levinthal (1990) first put forward the concept of AC, which refers to the ability of enterprises to identify and acquire new external information value, absorb information and apply it to commercial purposes. Zahra and George (2002) divide AC into potential absorptive capacity (PAC) and actual absorptive capacity (AAC). PAC includes knowledge acquisition and digestion, while AAC includes knowledge transfer and application. If PAC of enterprises is weak, it is difficult for organizations to understand and absorb external resources and information (Duan et al., 2020). Otherwise, the company can acquire and absorb external resources sufficiently, producing green products that meet market demand. AAC means that an enterprise obtains new insights from existing knowledge, and applies them to daily production and operation (Duan et al., 2020). If AAC is weak, an enterprise cannot grasp the industry technology, thus ignoring the potential opportunities in the market. On the contrary, it will help enterprises to integrate internal and external resources, promoting GI of enterprises.

AC can help enterprises overcome organizational inertia and break institutional conventions, so as to gain market competitive advantage (Miroshnychenko et al., 2021). Through AC of enterprises, from the identification and acquisition of external resources to the integration, digestion and application of internal resources, GI is promoted by the joint effect of internal and external knowledge and resources. Therefore, the following hypothesis is proposed:

H2: AC positively moderates the relationship between TMEA and GI.

1.3 Moderating role of slack resources

According to the resource-based view, only valuable, unique, difficult to imitate and hard to replicate resources are the key sources for enterprises to obtain sustainable competitive advantages (Bowen et al., 2010). Therefore, enterprises need to provide sufficient resources to ensure the implementation of innovation. The necessary resource support is the foundation for the success of GI. SR refers to the difference between the resources that an enterprise can have and the resources that it actually needs to maintain the status quo. SR can solve the problem of resource conflicts within the organization, acting as a "buffer" to protect the technological core of the organization from the impact of the external environment. It can also promote the implementation of new strategies to introduce new products and enter new markets (Tan & Peng, 2003). SR can be divided into unabsorbed slack resources (USR) and absorbed slack resources (ASR).

USR refers to idle flowing resources that can be applied to other projects quickly and flexibly. When enterprises have sufficient resources, they have the ability to invest in R&D, and are more inclined to invest in GI projects with environmental protection effects. Because GI has the characteristics of high risk and high investment, enterprise executives pay little attention to R&D technology and product development when enterprises cannot freely allocate resources. They are more inclined to pay attention to the short-term performance of enterprises (Xie & Wei, 2016). Therefore, their willingness and ability to carry out GI in R&D activities are very low. USR can alleviate the negative impact

caused by the failure of GI and provide a guarantee for enterprises. It can also improve the ability of enterprises to resist risks, which is conducive to the development of GI (Long & Chai, 2021). USR can help enterprise executives transform their environmental awareness into enterprise innovation behavior, that is, the more USR an enterprise has, the more resources it can provide for managers to carry out GI. Therefore, the following hypothesis is proposed:

H3: USR positively moderates the relationship between TMEA and GI.

ASR refers to the resources that have been used and absorbed by enterprises in production, operation and management. ASR has poor fluidity and activity. When an enterprise holds more ASR, managers will spend a lot of energy searching and disposing of them, which will increase the holding costs and management expenses (Xiao & Li, 2018). Excessive ASR makes it more difficult for enterprises to identify and utilize these resources. In this case, enterprises usually maintain the original development path, resulting in an increase in the time and cost of enterprise transformation and upgrading, which is not conducive to the development of GI (Li et al., 2018). ASR occupies more fixed assets of enterprises and makes it more difficult to obtain stable cash flows, which will have a negative impact on managers' decisions. In addition, managers perceive ASR as necessary to maintain existing production activities, but not sufficient to implement new strategies (Iyer & Miller, 2008). ASR is implicit and usually exists in the production processes within the enterprises. Because it is hard to search, it is rarely used for GI. Therefore, the following hypothesis is proposed:

H4: ASR negatively moderates the relationship between TMEA and GI.

Therefore, the theoretical framework is proposed and shown in Fig. 1.

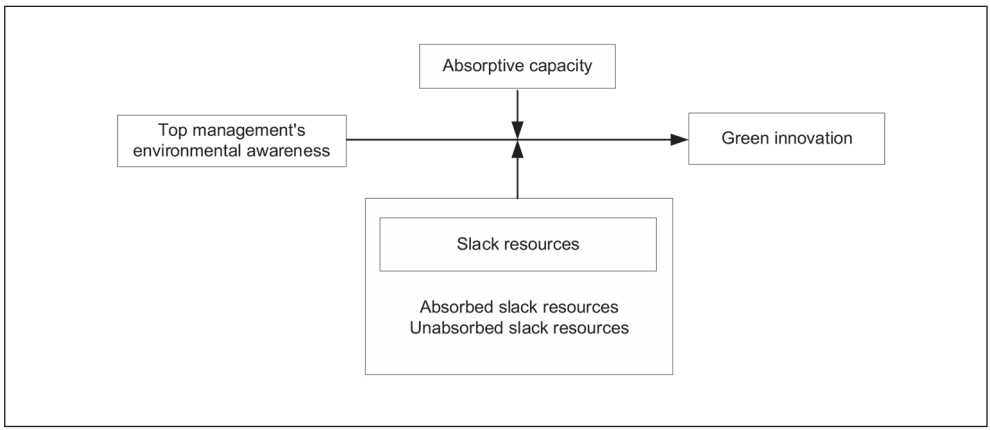

Fig. 1: Proposed theoretical framework

Source: own

2. Methodology

2.1 Sample and data collection

The research samples are from listed manufacturing companies in the A-share market of China. Compared with other industries, the manufacturing industry engaged in production activities has a greater impact on the environment. Under external pressure, there are more GI in manufacturing companies, and the number of patents is easier to collect. Given the availability of data, this paper selects Chinese manufacturing enterprises from 2010–2023 as the sample. According to the research of Hao et al. (2019) and Chen et al. (2018), the initial sample processing is as follows. First, eliminate special treatment listed companies (ST and *ST). Second, delete the companies with missing variables. Third,

the missing data of variables are manually filled with the average value of the previous year and the next year. A total of 816 valid observations were obtained. The data sources are as follows. GI comes from the CNRDS database, and TMEA comes from Wingo's financial text data platform. AC, SR and control variables are from the CSMAR database.

2.2 Measurements

We measured GI based on the study of Jiang et al. (2022) with the number of green patents applied by enterprises in the current year. The number of green patent applications includes the number of green inventions and the number of green utility models. The larger the number, the stronger the GI. In order to make the GI index more in line with the normal distribution, this paper adds 1 to the number of green patent applications and takes the natural logarithm.

TMEA was measured by the total word frequency of keywords add 1 and take the natural logarithm in corporate social responsibility reports adopted from Short et al. (2010). According to the definition of environmental awareness (Peng & Liu, 2016) and the questionnaire items (Gadenne et al., 2009), five keywords were extracted: environmental protection, environmental problems, environmental protection measures, environmental responsibility, and environmental policy. Through the deep learning function of similar words on WinGo's financial text data platform, keywords were found, and then similar words with similarity less than 0.5 were removed to get the keywords list. The total word frequency of the keywords appearing in CSR reports from 2010–2023 was counted.

AC was measured by R&D intensity according to Cohen and Levinthal (1990) and Rothaermel and Alexandre (2009) because considering the scales of enterprises. The formula is: R&D investment/operating revenues.

Referring to Wu and Hu (2016), we used ((selling expense + administrative expense)/ operating revenues) as a measure of ASR. This indicator reflects the amount of specific resources invested by the enterprise in sales and management activities.

Latham and Braun (2008) used the current ratio to measure USR, but enterprises with high indicator may not have strong short-term

Tab. 1: Variable descriptions

Variable type	Variable name	Abbreviation	Measurement
Dependent variable	Green innovation	*GI*	Add one to the number of green patents applied by the enterprise in that year, and take the natural logarithm.
Independent variable	Top management's environmental awareness	*TMEA*	Add one to the total word frequency of five keywords and take the natural logarithm.
Moderating variables	Absorptive capacity	*AC*	R&D investment/operating revenues
	Absorbed slack resources	*ASR*	(selling expense + administrative expense)/ operating revenues
	Unabsorbed slack resources	*USR*	Quick assets/current liabilities
Control variables	Firm age	*AGE*	The natural logarithm of the number of years since the firm's establishment
	Firm size	*SIZE*	The natural logarithm of the total assets of the firm at the end of the year
	Ownership type	*TYPE*	State-owned enterprises = 1 Non-state-owned enterprises = 0
	Financial leverage	*LEV*	Asset-liability ratio

Source: own

solvency. Therefore, we used the quick ratio as a measure of USR referring to Shimizu (2007). The formula is: quick assets/current liabilities. This indicator can more accurately reflect the ability of enterprises to repay short-term debts.

Control variables

Based on the related research, firm age, firm size, ownership type, and financial leverage were selected as control variables (Deng et al., 2021; Li et al., 2020; Nie et al., 2008; Xie, 2021; Xie & Zhu, 2021). We used the natural logarithm of the number of years since the firm was founded and the total assets at the end of the year to measure firm age and firm size, respectively. Ownership type was measured using a dummy variable (state-owned enterprises = 1, non-state-owned enterprises = 0). Financial leverage was measured by the asset-liability ratio. The descriptions of the variables are shown in Tab. 1.

2.3 Regression models

To explore the influence of TMEA on GI, the following regression equation was established.

$$GI_{it} = \alpha_0 + \alpha_1 TMEA_{it} + \alpha_2 X_{it} + \mu_{it} \quad (1)$$

where: GI_{it} – GI of *i* industry in *t* year; $TMEA_{it}$ – TMEA of *i* industry in *t* year; X_{it} – the control variables; μ_{it} – the random error.

To test the moderating effect, the following regression equation was further developed.

$$GI_{it} = \alpha_0 + \alpha_1 TMEA_{it} + \alpha_2 AC_{it} + \\ + \alpha_3 TMEA_{it} * AC_{it} + \alpha_4 X_{it} + \mu_{it} \quad (2)$$

where: GI_{it} – GI of *i* industry in *t* year; $TMEA_{it}$ – TMEA of *i* industry in *t* year; AC_{it} – AC of *i* industry in *t* year; X_{it} – the control variables; μ_{it} – the random error.

$$GI_{it} = \alpha_0 + \beta_1 TMEA_{it} + \beta_2 USR_{it} + \\ + \beta_3 TMEA_{it} * USR_{it} + \beta_4 X_{it} + \mu_{it} \quad (3)$$

where: GI_{it} – GI of *i* industry in *t* year; $TMEA_{it}$ – TMEA of *i* industry in *t* year; USR_{it} – USR of *i* industry in *t* year; X_{it} – the control variables; μ_{it} – the random error.

$$GI_{it} = \alpha_0 + \gamma_1 TMEA_{it} + \gamma_2 ASR_{it} + \\ + \gamma_3 TMEA_{it} * ASR_{it} + \gamma_4 X_{it} + \mu_{it} \quad (4)$$

where: GI_{it} – GI of *i* industry in *t* year; $TMEA_{it}$ – TMEA of *i* industry in *t* year; ASR_{it} – ASR of *i* industry in *t* year; X_{it} – the control variables; μ_{it} – the random error.

Equations (2–4) will test whether *AC* and SR play a moderating role between *TMEA* and *GI*.

3. Results

3.1 Descriptive statistics and correlation analysis

As shown in Tab. 2, we find that there are large differences in *GI* and *TMEA* among enterprises. From the maximum and minimum values of *AC* and SR, it can be concluded that the abilities of enterprises to transform external superior resources and knowledge, as well as the resources they own, are very different. From the mean value of *AGE*, *SIZE*, *TYPE* and *LEV*, we conclude that the enterprises have a long duration. There is little difference in the assets owned by the enterprises. Non-state enterprises are in the majority. The overall operation of the enterprises is relatively stable.

The correlation coefficient of each variable is less than 0.7, which preliminarily indicates that there is no multicollinearity problem among the variables. In addition, the maximum variance inflation factor is less than 3, which further indicates that multicollinearity was not a serious problem.

3.2 Regression results

We used a hierarchical regression analysis to test our hypotheses (Tab. 3). In Model 1, the control variables were entered first. The results reveal that *SIZE*, *TYPE* and *AGE* have significant positive effects on *GI*, but the relationship between *LEV* and *GI* was not significant. Next, *TMEA* was entered as an independent variable (Model 2), resulting in a positive and significant effect of *TMEA* on *GI* (α_1 = 0.692, $P < 0.001$). Thus, *H1* was supported.

Then, the moderating effect of *AC* on the relationship between *TMEA* and *GI* was tested using Model 3. The interaction term (*TMEA*AC*) was positive and significant (α_3 = 0.132, $P < 0.01$), indicating support for *H2*. To verify the moderating role of SR, we added *USR* and *ASR* into Models 4 and 5, respectively. The results showed that *USR* positively moderated the positive effect of *TMEA* on *GI* (β_3 = 0.137, $P < 0.01$) and *ASR* negatively moderated the positive effect of *TMEA* on *GI* (γ_3 = −1.260, $P < 0.01$). Thus, *H3* and *H4* were supported.

Tab. 2: Correlations and descriptive statistics

Variables	1	2	3	4	5	6	7	8	9
1. *GI*	1.000								
2. *TMEA*	0.053***	1.000							
3. *AC*	0.050***	0.016*	1.000						
4. *USR*	0.076**	−0.043	0.089**	1.000					
5. *ASR*	0.172***	0.023*	0.575***	0.122***	1.000				
6. *SIZE*	0.083**	0.054**	−0.020	−0.387***	−0.184***	1.000			
7. *LEV*	0.085**	0.052	0.104***	−0.671***	−0.272***	0.621***	1.000		
8. *TYPE*	−0.060*	−0.093***	0.230***	−0.074**	0.080	0.218***	0.117***	1.000	
9. *AGE*	0.031**	−0.127***	0.024	−0.203***	−0.033	0.284***	0.298***	0.124***	1.000
Mean	1.782	3.001	5.962	2.156	0.166	22.330	0.390	0.218	2.698
SD	0.834	0.288	4.305	2.241	0.089	1.070	0.170	0.413	0.408

Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Source: own

Tab. 3: Regression results

Variables	*GI*				
	Model 1	Model 2	Model 3	Model 4	Model 5
SIZE	0.132*	0.156***	0.184*	0.172**	0.186**
LEV	0.612	0.160	0.181	0.188	0.167
TYPE	1.028**	1.391***	1.106***	1.795**	1.125***
AGE	0.915**	0.712**	0.713*	0.710**	0.851**
TMEA		0.629***	0.438***	0.575***	0.875***
AC			0.621**		
*TMEA*AC*			0.132**		
USR				0.736**	
*TMEA*USR*				0.137**	
ASR					0.610***
*TMEA*ASR*					−1.260**
R^2	0.150	0.176	0.179	0.177	0.186
Adjusted R^2	0.065	0.056	0.049	0.053	0.052
F	18.860	18.210	13.880	14.810	14.960

Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Source: own

To interpret the interaction results, we plotted the moderation effect at one standard deviation above and below the mean for the moderating variables (Figs. 2–4). Fig. 2 and Fig. 3 showed that the relationship between *TMEA* and *GI* was stronger when *AC* and *USR* were stronger, which were in good agreement with *H2* and *H3*. Fig. 4 indicated that, compared with low *ASR*, the effect of *TMEA* on *GI* was weakened at a high level of *ASR*, supporting *H4*.

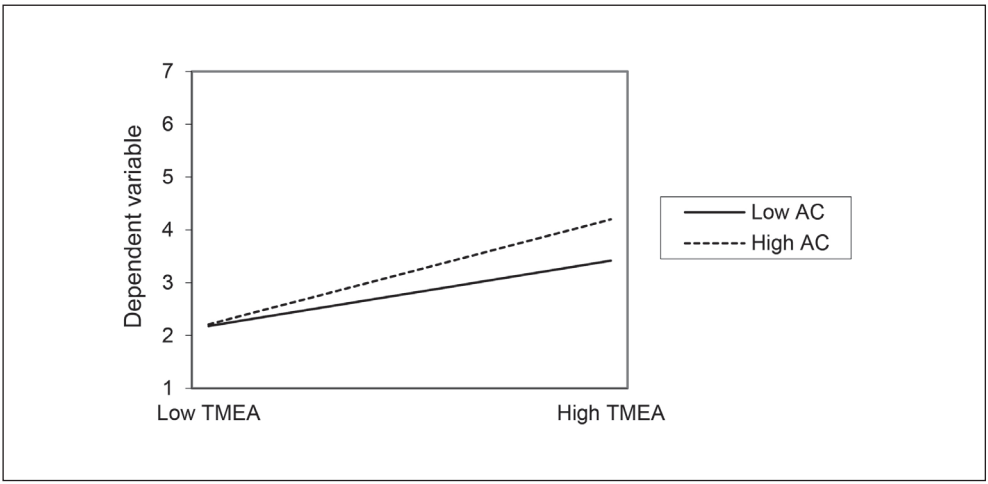

Fig. 2: **Moderating effect of AC between TMEA and GI**

Source: own

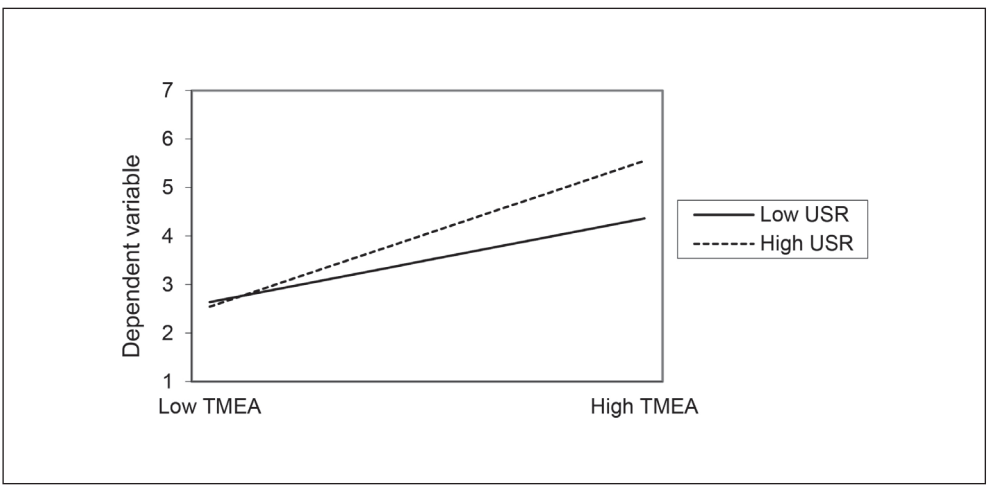

Fig. 3: **Moderating effect of USR between TMEA and GI**

Source: own

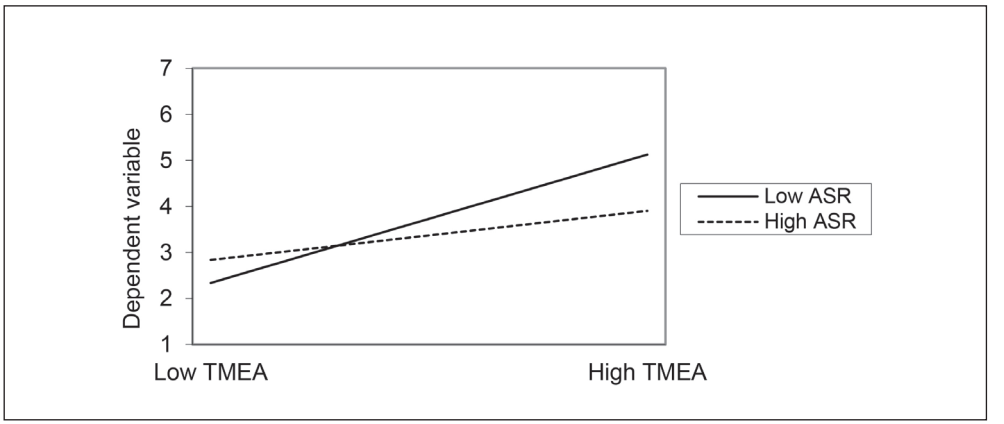

Fig. 4: **Moderating effect of ASR between TMEA and GI**

Source: own

3.3 Robustness test

We used two methods to test the robustness of the results. The first method is variable substitution. Referring to the previous studies, we used the ratio of the number of R&D personnel (Liu & Buck, 2007), the current ratio (Latham & Braun, 2008), and the ratio of administrative expenses to selling expenses (Yang et al., 2015) to measure *AC*, *USR* and *ASR*, respectively.

Tab. 4: **Variable substitution method**

Variables	Model 6	Model 7	Model 8
SIZE	0.178**	0.187**	0.176**
LEV	0.169	0.171	0.180
TYPE	1.089**	1.061*	1.078**
AGE	0.758**	0.872**	0.836**
TMEA	0.561***	0.585**	0.682**
AC	0.591**		
TMEA*AC	0.152**		
USR		0.656**	
TMEA*USR		0.135**	
ASR			−0.627***
TMEA*ASR			−0.258***
R^2	0.187	0.196	0.206
Adjusted R^2	0.046	0.054	0.059
F	13.520	14.720	15.010

Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Source: own

Tab. 5: Repeated random sampling

Variables	*GI*
TMEA	0.629***
	(6.160)
Company/code FE	Yes
Observations	816

Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Source: own

Tab. 4 shows that *AC* and *USR* have a positive moderating effect between *TMEA* and *GI*, while *ASR* has a negative moderating effect in this relationship, which is consistent with previous findings, indicating the robustness of the research results.

The second method is repeated random sampling. To alleviate sample selection bias, we used Bootstrap method to repeat random sampling 1,000 times. As shown in Tab. 5, the results are generally consistent with the previous regression results.

Conclusions

This study explores the relationship between TMEA and GI using manufacturing companies in China. First, TMEA has a significant positive impact on GI. The extent to which an enterprise responds to external environmental pressure depends on the level of TMEA. The stronger the TMEA, the better they can identify the potential resources, benefits and opportunities in the external environment, reasonably allocate and apply the internal and external resources and opportunities, and promote enterprises to carry out GI activities. Second, AC enhances the positive effects of TMEA on GI. The stronger the AC, the more efficient the enterprise can obtain resources and information from the external environment, and absorb, transform and apply them to the R&D investment of the enterprise, thus responding to market changes and demands in time, helping the enterprise to create its own competitive advantage and realize GI. Third, TMEA has a greater impact on GI in firms with abundant USR compared to firms with few USR. USR can improve the ability of enterprises to resist risks, reduce the negative impact caused by environmental uncertainty, and provide security for enterprises. When senior managers realize the importance of GI, enterprises will invest enough resources and capabilities to carry out GI activities. Fourth, ASR weakens the positive effect of TMEA on GI. ASR has poor liquidity because it has been applied to various production and management activities of enterprises. When enterprise resources are in short supply, it is impossible to conduct flexible scheduling, which reduces the efficiency of GI.

First, this study integrates upper echelons theory, resource-based view and dynamic capability theory, and puts forward the theoretical model of the influence of TMEA on GI. It adds to our understanding of how TMEA influence GI. Most of the previous studies have discussed influencing factors of GI from the perspective of external institutional pressure (Xu et al., 2017). However, they have not paid enough attention to the role of TMEA in promoting GI. This paper analyzes the key factors affecting GI from the perspective of internal resources and capabilities of enterprises, and discusses the influence of executives' perception and interpretation of different policies on GI behavior. The stronger the environmental awareness of executives, the more inclined they can actively allocate organizational resources to meet the enterprises' environmental strategy and obtain sustainable green competitive advantages (El-Kassar & Singh, 2019). This study helps us to better understand the mechanism of promoting GI in enterprises, and also provides useful reference for enterprises to carry out GI more effectively.

Second, one contribution of this study is to verify the moderating effect of AC on the relationship between TMEA and GI. AC is the ability of enterprises to acquire, transform and utilize internal and external resources

and knowledge to improve GI (Duan et al., 2020). TMEA will make enterprises pay more attention to external environmental information, but how to transform external resources into GI ultimately depends on the enterprises' internal AC. Although previous studies believe that AC is a key factor for enterprises to integrate and transform knowledge effectively, there is still a lack of research on how AC affects the relationship between TMEA and GI. Given the importance of AC, we verified that AC positively moderates the relationship between TEMA and GI. This study provides a new insight into the research of how to increase GI by investigating the moderating role of AC.

Third, this study verifies the moderating effect of SR between TMEA and GI. Previous studies have found that SR can play a positive role in promoting GI as long as enterprises can effectively use these resources, whether it is USR or ASR (Xie et al., 2020). Redundant resources of enterprises can reduce the cost of GI, thus maintaining their sustainable development. However, there are few studies on how TMEA affects GI from the perspective of SR. This study fills this gap. It is found that USR has high flexibility and low switching cost, which can play a role at any time in dealing with unexpected events in the environment and contributing to GI. ASR will increase the cost of enterprises, which is not conducive to GI. TMEA can help to determine whether an enterprise can make full use of internal resources, and turn external institutional and market pressure into opportunities for GI. Therefore, when enterprises carry out GI, they should consider TMEA and internal resources comprehensively. The study enriches GI theories and helps us to understand the driving mechanism of GI in enterprises.

Practical implications. This study has three implications for enterprise management and practice. First, because top managers are the key driving forces to formulate enterprise strategy, the government and society should strongly advocate the belief of green development, increase executives' attention to meet the green expectations of society, and improve managers' level of environmental responsibility. Top managers should pay more attention to the benefits of stakeholders, formulating plans and implementing specific measures that meet environmental protection standards. In addition, top managers should put GI at a strategic level and integrate it into product production within enterprises.

Second, enterprises should pay more attention to AC. With the promotion of green development of enterprises, the ability of enterprises to transform knowledge into results has become an important source of green competitive advantages. Therefore, enterprises should strengthen the training of organizational members and improve their learning ability, knowledge acceptance and transformation ability.

Third, enterprises should make scientific and reasonable decisions, fully understand the risk resistance function and improve the utilization rate of USR, maintain the flexibility of resource allocation, and enhance the vitality of GI. In addition, enterprises should control ASR to some extent, thus reducing the management cost of enterprises and saving human and financial resources. We should not only pay attention to the strengthening of TMEA, but also pay attention to the integration of resources and the improvement of capabilities.

Limitations and future directions. There are some limitations in this study, which also provides a direction for future research. First, this paper investigates the influence of TMEA, AC and SR on GI of manufacturing enterprises, which supplements the application of GI research in manufacturing industry, but the research conclusions are not universal. Due to the particularity of GI, the specific situation of GI may be different in different industries. Therefore, whether the conclusions of this study are valid in other industries needs further discussion. Second, there are limitations in the research samples and measurement indicators. The selected samples only include listed manufacturing enterprises in China, and the sample size only meets the theoretical needs. The scope and sample size can be expanded in future research. Regarding the measurement indicator, TMEA measured by keywords may deviate from the actual environmental awareness of executives. Future research can be combined with questionnaires and secondary data measuring TMEA more accurately. Third, we only discuss the moderating roles of AC and SR in the relationship of TMEA and GI. In the future, we will explore other variables affecting this relationship, seeking to enrich the existing theories.

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The lens of business model element activation

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Abstract: *A business model is the foundation for understanding the functioning of a business entity and is a source of innovation and change. Therefore, developing a business model is necessary, and proactive activation can be a source of competitive advantage to meet the appropriate requirements in the composition of business model elements. The study aims to identify the key elements of activation in business models and to discover their significance. This study uses an expert-based approach based on the use of multi-criteria decision-making (MCDM) with the definition of the main elements. It also compares data from fuzzy analytical hierarchy process (AHP) and conduct primary research among small and medium-sized enterprises (SMEs) to determine the importance of various elements in their business models. It provides insight into determining the degree of significance of business model elements, with its expansion to the Delphi method and a panel of experts on 97 sub-criteria. Predominant factors such as value proposition, customer segments, and key partnerships have been identified as primarily critical for SMEs. The results obtained can then be used by businesses for subsequent concentration on a specific business element to achieve higher company performance and strengthen the competitive position. This study presents a fresh perspective on reimagining the classification of business models, their elements, and, above all, the determination of the meaning of individual business model criteria.*

Keywords: *Business model, fuzzy multi-criteria decision-making (MCDM), small and medium-sized enterprises.*

JEL Classification: *D20, D24, M21, O33.*

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Introduction

Nearly all business owners and managers strive for high performance from their businesses. Trends in the development of digitization, technology, and regulatory changes, along with changing customer and competitor behavior (Latifi et al., 2021), have an impact on adequate responses to maintain a certain dynamism and business activation. In order to grow, increase profitability, and survive, companies must adapt their business strategies (Vukanović, 2016). The business model canvas (BMC) is used to operationalize and visualize a business or a business unit's functioning (Osterwalder & Pigneur, 2010). It is also used in connection with business model innovation (BMI) when the authors look for factors affecting the company's performance and the mutual influence of individual elements of the business model. BMC is also used for the categorization and typology of the functioning of business entities (Gassman et al., 2014). The novelty of the study is in the area of a detailed view of the importance of elements of the business

model. There are already studies focused on examining the performance of companies using key performance indicators (Freisinger et al., 2021), there are also studies related to the importance of BMI and its effects (Latifi et al., 2021), but studies focused on decision-making for entrepreneurs or managers, which are the factors of the business model that are primary for concentration, are missing here. Accordingly, there is the question: Is it possible to use the BMC to capture the influence of individual, "traditional" nine elements in the sense of categorization and defining the weights (importance) of individual elements? Therefore, the study aims to identify key elements of activation in business models and to discover their significance for competitiveness through the identification of the key BMC element using the fuzzy AHP method. A partial goal is to compare data from the fuzzy analytical hierarchy process (AHP) and conduct primary research among small and medium-sized enterprises (SMEs) to determine the importance of elements of the business model (BM) concerning competitiveness. For example, a study by Vasilienė-Vasiliauskienė et al. (2020), confirms the significance of the concentration on selected elements of BMC that have an impact on the competitiveness of the enterprise. The obtained results can be used by companies for subsequent concentration on a specific element to achieve higher company performance and strengthen the competitive position.

The study points out and applies a procedure that can be used to identify the degree of importance of individual BMC elements. The study wants to capture the parameters to determine the activation of the business model, i.e., influence a specific value from the standpoint of micro-, small-, and medium-sized businesses. Understanding the importance of the factors in these clusters will help to understand the concentration of attention of their owners to strengthen the elements that are important to them from the point of view of competitiveness.

The research is organized in the following manner. Initially, the literature review establishes the foundational theoretical concepts pertaining to business models (BM) and the constituent elements of business models, focusing particularly on the processes of BM identification and the allocation of sub-criteria. Theoretical frameworks serve as a basis for the subsequent acquisition of empirical data and the identification of the most salient factors impacting the competitive positioning of enterprises through BM elements. The following part contains a description of the methods and successive steps of the research in individual steps. Then, the Delphi method, primary research, and fuzzy AHP are described, mainly to establish the weights of the BM elements. Subsequently, results, discussions, and implications are presented, concerning SME clusters and identified differences and significance between individual BM elements. In conclusion, the final observations afford an opportunity for the dissemination of knowledge and the practical ramifications for those in positions of decision-making authority.

1. Theoretical background

The business model facilitates the operational execution of the organization and is a management tool for deciding on mutual elements of its development and innovation. It is difficult for companies to define the degree of influence of a specific element in the functioning of their business. In this context, it is possible to include the current complexity theory as a novel addition to the comprehension of intricate entities such as BM (Foss & Saebi, 2017, 2018; Lanzolla & Markides, 2021; Massa et al., 2018). The application of the complexity approach in BM studies lies in its ability to clarify and present specific aspects of the complex system and its integration.

The very architecture of complexity is determined by hierarchy, which Simon (1991) understands as a hierarchical system referred to as a complex system that can be analysed into a possible set of subsystems that exist after each other (Amit & Zott, 2010). When considering BM, researchers emphasize the system of activities and assume BM as an architecture of mutually valuable subsystems (Teece, 2010). The modularity of BM research is constantly developing to the potential of innovation (Freisinger et al., 2021; Minatogawa et al., 2018), to the mutual dynamic aspects of BM (Adámek & Meixnerová, 2022) or the concept of complementarity and interdependence.

In the realm of literature examination, a deficiency persists in the correlation between small and medium-sized enterprises (SMEs) and the effects of business models (BMs), and a comprehensive systematic literature review remains conspicuously absent (Tullio

& Tarquinio, 2021). Therefore, this study expands the concept and examines the degree of significance of BM factors from the perspective of its sub- and main elements. Czech enterprises are likewise not exempt and are compelled to address the challenges linked to recovery, which includes emphasizing suitable strategies to guarantee the continuity of the enterprise.

Empirical analysis reveals that small and medium-sized enterprises (SMEs) have experienced a range of constraints and market disruptions, alongside emergent opportunities, as a consequence of the economic shock induced by the COVID-19 pandemic (Adam & Alarifi, 2021). The authors' consulting engagements positively influence the understanding of business models (BM) in small businesses by facilitating a deeper comprehension of organizational dynamics and acting as a driver for innovation and the formulation of new strategic initiatives. Furthermore, the business model (BM) serves as a foundational driver of both strategic development and innovation (Afuah, 2019).

The BM functions as a critical tool for understanding the operationalization and functioning of a firm, offering a valuable framework for SMEs. It aids owners, managers, and entrepreneurs in comprehending the underlying logic and structure of their business operations. The core elements emphasize the creation and capture of value through the delivery of a compelling value proposition to customers (Amit & Zott, 2010; Zott et al., 2011). Moreover, the business model (BM) facilitates the visualization and comprehension of a firm's primary activities, value propositions, and critical resources. Various approaches to business modeling have been developed and applied in the literature., e.g., Gassmann et al. (2014), Osterwalder and Pigneur (2010) and Wirtz (2011). These approaches offer a foundational framework for the business model (BM) to represent the structure of a firm and can be further extended through conceptual refinement and comparative analysis (Steinhöfel et al., 2016).

We find that the relevance of business model canvas is applied in the contemporary references to analyse the empirical insight, i.e., how we can operationalise business and look for potential areas for higher validity of business models. The study employed the BMC developed by Osterwalder and Pigneur (2010), which facilitates the construction of a business model through nine interrelated components: value propositions, customer segments, customer relationships channels, revenue streams, key activities, key partners, cost structure, and key resources. Furthermore, business models can serve as tools for analyzing and assessing components that represent an analytic capacity (Chungyalpa et al., 2016) to examine the interrelationships among the components of the business model. This approach has been shown to be comprehensive, as its building blocks (elements) provide a detailed and integrated perspective on the structure and dynamics of business models (Wirtz et al., 2016). Therefore, based on the literature,

Tab. 1: Summarization of dimensions, elements, and sub-elements of the business model

Dimensions	Questions	Main element	Sub-elements
How	How does a business deliver value through resources and capabilities?	Infrastructure	Key activities Key resources Key partners
What	What is the unique value proposition, the key offer of a business?	Offering	Value proposition
Who	Who is the customer and what are their needs?	Customer	Customer segments Customer relationships Channels
Value	How does a business capture value through a revenue model?	Finance	Cost structure Revenue streams

Source: own (based on Gassmann et al. (2014) and Osterwalder & Pigneur (2010))

we selected the basic four dimensions (How, What, Who, Value), categorised the key questions (Gassmann et al., 2014) with an extension to the main element (infrastructure, offering, customer, finance), then they were divided into sub-criteria using BMC logic (Osterwalder & Pigneur, 2010). The result is Tab. 1, which summarises the logic and synthesis of the findings, which are used further for research.

Numerous scholars in the field of business model research examine the components of business models and their implications for competitive advantage. Furthermore, SMEs demonstrate considerable flexibility and adaptability, exhibiting multitasking capabilities, reduced bureaucratic structures, and a swift responsiveness to change, thereby facilitating rapid implementation of innovations (Arbussa et al. 2017) attributable to their relatively small size and structural simplicity. Creating universal business model patterns for SMEs may not be practical. However, analyzing the significance of specific business model elements within different cohorts can provide valuable insights. Therefore, future research is also applied to SMEs, so that we can identify partial weights of individual BM elements in these clusters.

2. Research methodology

This study seeks to identify and evaluate the significance of business model elements specifically within the contexts of micro, small, and medium-sized enterprises. The methods are combined in a gradual research logic (Fig. 1), where the Delphi method is used to collect and clarify the criteria of BM, which summarises and categorises the criteria and provides the results for the AHP matrix from the perspective of an expert panel (Ikart, 2019). The study research methodology (Fig. 1) begins with "Step 1" when the structure of the business model and its elements are presented. This is followed by "Step 2," which determines the elements of BM and compares the most significant studies. These findings are further used for "Step 3" when a panel of experts is established and we move to "Phase 1," which begins with the implementation of the Delphi method to identify elements of BM "Step 5" for the hierarchical decision tree. "Step 6" subsequently operationalises the data to determine weight-based rankings of the BM elements. This is followed by "Phase 2," which applies fuzzy AHP "Step 7" as a basis for the subsequent creation of a questionnaire and its execution "Step 8", which is a tool for the practical identification of BM elements in a sample of small businesses "Step 9." The last is "Phase 3," which evaluates and compares the data and determines the outputs and results' "Step 10." The individual research methodology is gradually applied throughout the contribution and complements its content level.

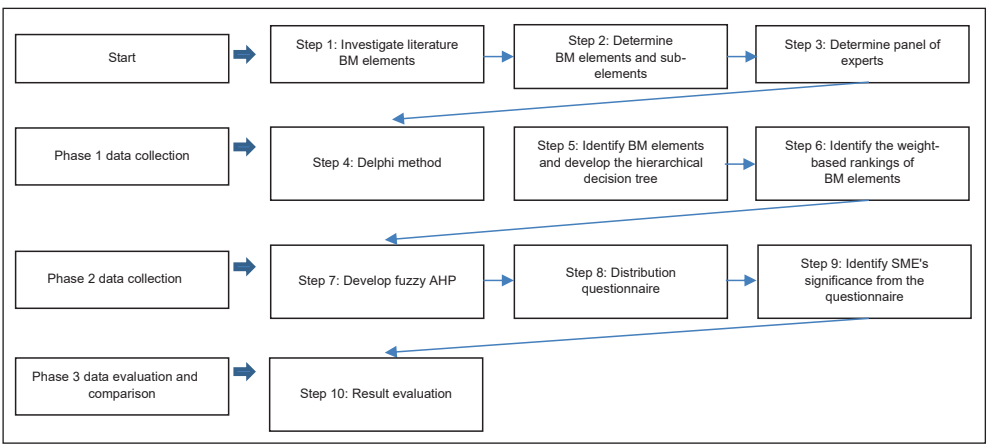

Fig. 1: Research design

Source: own

Consequently, primary research is also conducted among 150 companies in the field of micro, small, and medium companies, where the categorisation and structure of BM elements are used in the form of 97 elements.

The research was carried out (October to December 2022), interviews with business owners were carried out in person or via an online tool (e.g., MS Teams, Skype), and the representation was selective (even between each cluster). The method of selecting the sample of respondents is based on a permanent panel. This panel was developed on non-probability sampling, using purposive sampling according to the characteristics of SMEs. Given that BM can be divided into individual elements and sub-elements, it is possible to use a multi-criteria decision-making (MCDM) situation (Vatankhah et al., 2023). Therefore, MCDM techniques serve as robust decision support systems, enabling a precise and systematic evaluation and selection of specific business model elements. The application of MCDM techniques in organizational decision-making is becoming increasingly significant and widely recognized in business research (Chen & Chen, 2018; Raj et al., 2022). MCDM techniques are deterministic tools and can be used for classification, sorting, and determination of preference and significance for future decision-making (Lai & Ishizaka, 2020).

The study employed an expert-based approach based on the use of MCDM with the definition of the main elements based on the review of sources, utilizing a fuzzy Delphi method to ascertain the significance of the elements, combined with a fuzzy analytic hierarchy process (AHP) to establish the relative priorities among the components of the business model configuration. This study suggests fuzzy AHP as a useful method to determine important elements of business models. Fuzzy MCDM techniques employ linguistic terms, such as “strong” or “very weak,” to capture and interpret experts’ opinions on the relative importance of the criteria being evaluated (Vatankhah & Darvishi, 2021). Expert evaluation relies on triangular fuzzy numbers (TFN). A TFN is a type of fuzzy set characterized by three pivotal points, typically represented as $\tilde{M} = (l, m, u)$. The parameter *l* denotes the minimum value within the fuzzy set, *m* signifies the most likely or central value, and *u* represents the maximum value within the set. A TFN can be represented using the Equation (1) (Zadeh, 1965).

$$\mu(\tilde{M}) = \begin{cases} 0, x < l \\ \frac{x-l}{m-l}, l \le x \le m \\ \frac{u-x}{u-m}, m \le x \le u \\ 0, x > u \end{cases} \quad (1)$$

Several operations can be performed on triangular fuzzy numbers. If $\tilde{M}_1 = (l_1, m_1, u_1)$ and $\tilde{M}_2 = (l_2, m_2, u_2)$ are two different TFNs, then:

Fuzzy addition ($\oplus$) can be performed as:

$$(l_1 + l_2, m_1 + m_2, u_1 + u_2) \quad (2)$$

Fuzzy subtraction ($\ominus$) can be performed as:

$$(l_1 - l_2, m_1 - m_2, u_1 - u_2) \quad (3)$$

Fuzzy multiplication ($\odot$) can be performed as:

$$(l_1 * l_2, m_1 * m_2, u_1 * u_2) \quad (4)$$

Fuzzy division ($\oslash$) can be performed as:

$$(l_1, m_1, w_1)^{-1} = \left(\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1}\right) \quad (5)$$

where: *l* – the lowest possible value; *m* – the most promising value; *u* – the largest possible value.

The expert evaluation used triangular fuzzy numbers, so the fuzzy set has this significance.

2.1 Delphi method

The Delphi method was used to determine the relevant questions and structure of the questionnaire, this approach provides tools for uncovering the nuanced understanding of intricate phenomena (Denzin & Lincoln, 2005). Furthermore, the Delphi method was developed as a practical research tool to provide actionable insights for real-world applications. In the Delphi method, questionnaires are commonly employed for data collection because they offer a convenient means of gathering expert opinions (Brady, 2015). Since we need to clarify the possible structure of the questionnaire to obtain qualitative data, it is necessary to perform a certain summarization and categorisation of the elements of business models that were presented in the literature review. It is possible to implement the Delphi method using participatory community research (Israel et al., 1994), which is a step toward determining

specific BM factors and their categorisation (Tab. 1). Since we want to apply the comparison of BM elements in the SME sector, we created a selected group of experts, and the implementation took place in September 2022 in several rounds.

The empirical approach was based on a panel of Czech experts. The panel consisted of highly skilled people in a business ecosystem; specifically, there were 10 experts, three of whom were from the area of business support ecosystems, two academics, three experienced small businesses, and two were from the area of successful start-up small businesses. The sample set of experts was selective and determined so that they could identify their level of agreement for each item (CS – customer segments, VP – value propositions, CH – channels, CR – customer relationships, RV – revenue streams, KR – key resources, KA – key activities, KP – key partners, C – cost structure). As a methodology, BMC was used with sub-questions in each of the nine categories (a total of 97 items). The experts first understood the group of questions about BMC and expressed themselves on the possible categorisation of the BM criteria, and then these categorisations were decomposed into individual sub-criteria. After consensus on the structure of the questions, the experts themselves provided answers on a Likert scale (i.e., from 1 means low significance, to 5 means high significance) to the importance of individual criteria, as well as the overall impact on the main BMC criteria. The output of the expert panel was a specific structure of the questionnaire with a breakdown of the main BM and their sub-criteria, including determining the significance of the criteria in the creation of the AHP matrix.

2.2 Fuzzy AHP

The use of AHP is one of the most popular techniques that allow pairwise decision-making (Vaidya & Kumar, 2006). In the case of deciding where to direct the concentration of company owners, AHP is used because it allows concentrating on the main criteria (BM elements) so that the potential for business achievement. It is not possible to balance all criteria of the BM model with the same importance. Therefore, a weight-based calculation will allow those who decide to identify essential criteria and possible further steps in the implementation of sub-criteria. According to the weighted size of the given criterion, its significance is also assigned. Fuzzy AHP is used to eliminate vagueness in human judgments using crisp values (Vatankhah et al., 2023). Therefore, fuzzy AHP uses linguistic variables (Tab. 2).

According to Chang's extent analysis (Chang, 1992), if $X = \{x_1, x_2, \ldots, x_n\}$ is the object set and $U = (u_1, u_2, \cdots, u_m)$ is the goal set, there can be m extent analysis values for each object: $U_{gi}^1, U_{gi}^2, \ldots, U_{gi}^m$, $i = 1, 2, \cdots, n$.

Chang (1992) uses TFNs in this analysis to calculate the value of the fuzzy synthetic extent of the i^{th} object for the 'm' goals as follows:

$$S_i = \sum_{j=1}^{m} U_{gi}^j \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} U_{gi}^j\right]^{-1} \quad (6)$$

Equation (6) contains S_i, which involves the fuzzy extent analysis for the i^{th} object, the two distinct values are multiplied using the fuzzy multiplication operator. Assuming that U_g^j is a TFN represented as (l_{im}, m_{im}, u_{im}), $\sum_{j=1}^{m} U_{gi}^j$ can be calculated for the m extent analysis values using the fuzzy addition operator as $(\sum_{j=1}^{m} l_{ij}, \sum_{j=1}^{m} m_{ij}, \sum_{j=1}^{m} u_{ij})$.

Tab. 2: Fuzzy AHP linguistic terms and triangular fuzzy numbers

Linguistic scales	TFN	Description
Equally significant	(1, 1, 1)	Criteria A and B share the same importance.
Somewhat more significant	(2, 3, 4)	Criterion A is moderately more important than criterion B.
Considerably more significant	(4, 5, 6)	Criterion A is strongly more important than criterion B.
Substantially more significant	(6, 7, 8)	Criterion A is very strongly more important than criterion B.
Of greater significance	(8, 9, 10)	Criterion A is more important than criterion B.

Source: Vatankhah et al. (2023)

To reverse a value, use the fuzzy addition operator for values in the brackets, then apply the fuzzy division operator to get the reversed value. The calculation of the weight vector involves determining the degree of possibility that one triangular fuzzy number (TFN) exceeds another TFN, i.e., $S_i = (l_i, m_i, u_i) \geq S_k = (l_k, m_k, u_k)$, using Equations (4–5):

$$V(S_i \geq S_k) = sup_{y \geq x}[(\mu_{Si}(x), \mu_{Sk}(x))] \quad (7)$$

The degree of possibility that a convex fuzzy number exceeds k convex fuzzy numbers is evaluated using the principles of fuzzy set theory.

$$V(S \geq S_1, S_2, ..., S_k) = V[(S \geq S_1) \text{ and } (S \geq S_2) \text{ and } ... \text{ and } (S \geq S_k)] = \\ = \min V(S \geq S_i), i = 1, 2, 3, ..., k \quad (8)$$

Assuming that $d'(A_i) = \min V(S_i \geq S_k)$, for $k = 1, 2, \ldots, n; k \neq i$, then the fuzzy weight vector can be represented as:

$$w' = (d'(A_1), d'(A_2), ..., d'(A_n))' \quad (9)$$

Hence, w' represents a weight vector that incorporates the minimum values of the degrees of possibilities determined earlier. To calculate the "defuzzified" weight vectors where 'w' is a non-fuzzy number, divide each value in the fuzzy weight vector by the sum of all the values in the fuzzy vector. This normalization process ensures that the weights are scaled appropriately. The normalization equations are as follows:

$$w_i = \frac{w_i'}{\sum w_i'} \quad (10)$$

$$w = ((d(A_1), d(A_2), ..., d(A_n)) \quad (11)$$

3. Results

Data from questionnaire collection are evaluated according to the significance of individual criteria, which express the geometric averages of the answers obtained. So, they represent a 5-point Likert scale (1 minimum significance, 5 maximum significance). Fig. 2 shows the results of the questionnaires and data for each of the three cohorts of SMEs and the importance they attribute to individual factors of BM.

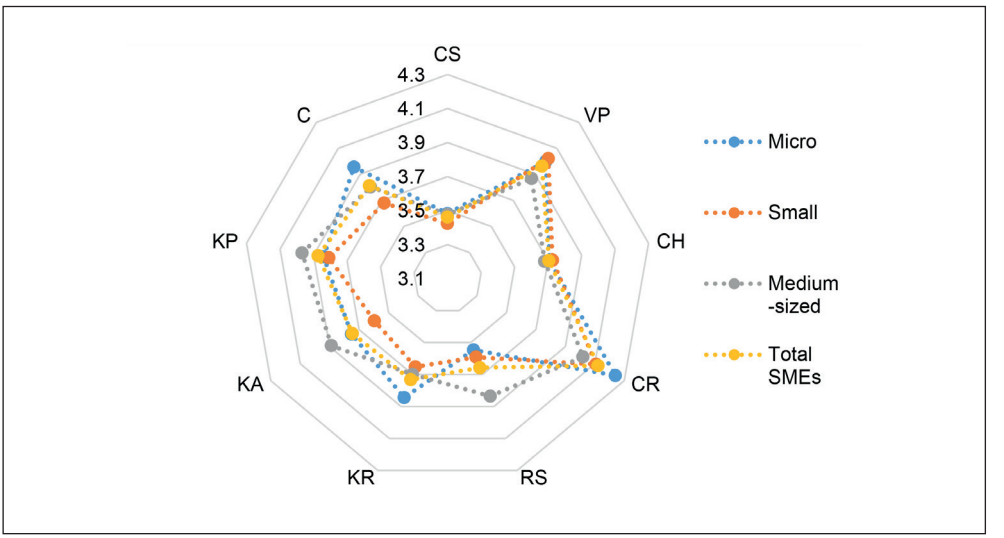

Fig. 2: Signification of business model elements in SMEs

Note: CS – customer segments; VP – value propositions; CH – channels; CR – customer relationships; RV – revenue streams; KR – key resources; KA – key activities; KP – key partners; C – cost structure.

Source: own

The data point to differences between the individual monitored cohorts, where, first, micro-enterprises monitor their importance in CR (4.2), then in VP and C (4.0) (Fig. 2). This means that these small businesses see their concentration in the value offered and maintaining relations with customers, including monitoring the development of cost and income. This significance reflects the fact that these companies accurately calculate their revenues and focus on value-added and customer relations.

Secondly, even for small companies, this is no different, and the importance of CR (4.1) and VP (4.0) prevails here, but interest in key partnerships (3.8) comes to the fore. This change is also evident in medium-sized businesses, where CR and KP (4.0) are the most important, followed by VP and KA (3.9) (Fig. 2). These companies are already larger and have a certain amount of capital, which is why factors aimed at maintaining relationships with customers and partners are important for them. These factors are also accompanied by the influence of the value offered and the internal factor of key activities.

According to the fuzzy AHP and Chang's (1992) extent analysis performed, we arrived at a pairwise comparison matrix for BM elements. As shown in Tab. 3, the most significant element of BM is customer segments (0.320), followed by the factor value proposition (0.247) and channels (0.126), respectively. The results suggest that customer segments are the most significant of all monitored elements, which is in contrast to empirical research, where the dominant factor was the customer relationship in the total of SMEs (Tab. 3).

These outputs point to the fact that the greatest concentration and significant attention should be directed to the area of market segmentation and the definition of the target customers with the definition of the offered value. That is, connectivity with the offered value and customer segment is key from the point of view of the construction of the company's business model. When calculating the consistency ratio, a value of 0.21 was reached, which indicates a failure to meet the criterion of less than or equal to 0.1. In addition, it depends on the sample characteristics (nine factors examined) and the analysis (group and/or individual). For individual experts, CR is restricted to 0.10 or 0.15, while for group responses, CR could be relaxed to 0.20 to allow responses following the recommendations (Ho et al., 2005).

If we generalise the resulting data, we will find that there is an agreement in the element of the value proposition business model, both for individual SMEs and for the recalculated coefficients for the total weights of the BM element (Tab. 4), which was multiplied through individual significant from primary research. In summary, to determine the most important factors in the construction of a business model and also in innovation, companies must consider customer segments and the value offered.

Tab. 3: Fuzzy weights

BM element	Final fuzzy weights			Normalized weight (*w*)
CS	0.217	0.322	0.465	0.320
VP	0.179	0.250	0.348	0.247
CH	0.081	0.126	0.190	0.126
CR	0.058	0.086	0.127	0.086
RS	0.051	0.070	0.096	0.069
KR	0.044	0.062	0.092	0.063
KA	0.025	0.036	0.054	0.037
KP	0.024	0.036	0.060	0.038
Cost	0.010	0.014	0.020	0.014

Source: own

Tab. 4: Fuzzy AHP linguistic terms and triangular fuzzy numbers

BM element	BM element weights (*w*)	BM element significance from primary research				BM element total weights		
		Micro	Small	Medium-sized	Total SMEs	Micro	Small	Medium-sized
CS	0.320	3.483	3.424	3.477	3.461	1.113	1.094	1.111
VP	0.247	4.000	4.022	3.869	3.964	0.989	0.994	0.957
CH	0.126	3.709	3.727	3.680	3.705	0.468	0.471	0.465
CR	0.086	4.240	4.108	4.020	4.122	0.366	0.355	0.348
RS	0.069	3.547	3.591	3.836	3.658	0.245	0.248	0.265
KR	0.063	3.844	3.652	3.700	3.732	0.242	0.230	0.233
KA	0.037	3.752	3.596	3.888	3.745	0.137	0.131	0.142
KP	0.038	3.840	3.808	3.968	3.872	0.146	0.144	0.151
Cost	0.014	3.956	3.680	3.804	3.813	0.056	0.052	0.054

Source: own

3.1 Discussion and implications

According to Adámek and Meixnerová (2020), the distinct components of a business model and its underlying dynamics can drive competitive advantage. By revisiting and adapting these elements and their contexts, companies can channel their efforts toward impactful innovations and transformations. However, it is not explicitly determined what influence the individual elements of BM should have, and it is desirable to examine this from the point of view of the concentration of decision-makers for achieving long-term development and dynamism of BM. To address the "so what" question, use the hierarchy of business model elements to highlight their importance and adopt a fuzzy AHP approach; this study allows us to look at BM elements more closely by assessing the relative importance of each criterion overall. In light of the current presence, this era opens a new challenge for sustainable business transition (Cohen, 2020).

Therefore, we can see the managerial implication of concentration on suitable BM elements. These findings can help managers and entrepreneurs understand activation, and the important role of BM and its specific factors (CS, VP, CH). Even for beginning entrepreneurs, concentration on these factors is key, and if they clarify their VP and segments, and appropriately apply communication tools in channels, they are a source for subsequent revenue generation, from which they can then cover their costs and reinvest surpluses for performance. Within this context, the importance of business modeling in focusing on the main elements of offering and customer is essential. Whether it is a start-up entrepreneur, an existing company, growing or strongly expanding, key decisions about these factors can be recommended as primary. A key approach is to be managerially focused on the connection between Who and What followed by How with the addition of the financial level and capture of revenue streams. Following on from the findings of the study and agreeing that the innovation of business models is in its elements (Freisinger et al., 2021), we expand this by identifying the specific meaning and specificity for SMEs.

On the contrary, fuzzification helped to determine the weights of the criteria, and here is a clear recommendation for any change, BM proposal, or its development, so always recommend concentration on the basic logic of the connectivity of value proposition and customer segments, which is further supported by the importance of channels. Theoretical implications expand the concept of the importance of elements of business models that have not been examined from the point of view of the importance of individual factors (which are

more important than others). The study uses a combination of research methods that were not used to determine the importance weights of individual BM elements. This also confirms the basic logic, when it is necessary to operationalize these three aspects first and then concentrate on other parts of BM. Generally speaking, businesses need to create and deliver value to survive and thrive, and therefore knowing which factor is important from the point of view of business modeling is important for them. This study helps shape decisions about the primary focus on the value proposition and the specific segment of the customer and the building of relationships.

Despite its contributions, the results of the study are subject to limitations. Firstly, the sub-criteria were not partially examined, only the main nine criteria were examined in the fuzzy AHP. A possible step is to extend the Delphi method with fuzzy principles based on the data obtained from the panel of experts. Second, the panel of experts provided the basis for weight comparison and significance, these results represent their view, when even the CR did not reach the required interval of 0.1 (it was accepted due to group decision consensus and nine evaluated criteria). Third, the study compares the results between weight criteria and significance criteria (SMEs perspective), but the latter is based on a sample of one hundred and fifty companies, which is only a partial representation of Czech companies. However, the results pointed to the fact that companies must consider customers and the real value offered when managing a company. Finally, generalised results are used that combine the view of fuzzy AHP weights and the importance of SMEs from the view of companies. Therefore, current knowledge can be used for future research incorporated.

Conclusions

Despite the awareness of the importance of BM for an organisation's success in business, in particular SMEs, there has been little consensus on its basis. The study provided insight into the determination of the importance of the elements of business models using the BMC methodology with its expansion to the Delphi method and a panel of experts on 97 sub-criteria. These were subjected to primary research and the predominant factors (VP, CR, and KP) were determined in the observed clusters of SMEs. The significance of the weights was determined using fuzzy AHP, where the factors (CS, VP, and CH) prevailed; their significance is essential for considerations of what to focus on when constructing the company's business model and specific measures.

Overall, the results underscore the paramount significance of the customer segments and value proposition elements within the business model, which stand out in terms of their overall importance. In times of rapid change driven by external factors, firms seek essential strategies to strengthen relationships with their customers. Firms differentiate their segments and relationship types by enhancing additional services and improving customer communication. They are digitizing processes like customer support, feedback systems, and purchase tracking, allowing customers to interact and respond swiftly, creating a seamless experience. SMEs focus on two main areas: value proposition and customer relationships. They are aiming to create standout products or services and build strong, responsive connections with their customers. This approach helps them attract and retain customers, adapting to market changes and staying competitive. Rather as a specific part of SMEs perceives it differently in orientation toward key partnerships, especially in connection with their suppliers. This trend signifies a preference for long-term supply stability and strategic collaboration with key partners. The importance of these relationships is particularly evident during periods of economic crisis or inflationary pressures on input costs. During such times, partnerships with reliable suppliers become critical to maintaining operational continuity. Economic fluctuations have already led to instances where companies, unable to absorb abrupt cost increases, have been forced to cease operations. In energy-intensive industries, the volatility of input prices has exacerbated the risk, resulting in the loss of consistent suppliers for some enterprises. This underscores the crucial role that strategic supplier relationships play in navigating economic uncertainties. The study provides a new perspective on the possibilities to think about the categorisation of BM, its elements, and, above all, on determining the meaning of individual BM criteria.

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Success drivers of equity crowdfunding campaign. Empirical evidence from Poland

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Abstract: *The success factors of equity crowdfunding are already well recognized in the literature but have not previously been studied in Poland. The aim of the paper is to fill the research gap by identifying the determinants of equity crowdfunding success in Poland based on empirical data. The article investigates whether and how entrepreneurs' conscious use of the non-financial benefits linked to equity crowdfunding (ECF) influences the campaign's success in Poland. We used data from a survey on the determinants of the success of equity crowdfunding. We conducted the survey using CAWI and CATI methods between September 2021 and January 2022 in collaboration with the Biostat Research and Development Centre as well as Beesfund, Crowdway and FindFunds platforms. Fifty-six companies accepted the invitation to participate in the study. Ultimately, the logistic regression model estimation was based on data obtained from 49 companies (28 of which had already succeeded in the equity crowdfunding campaign). Using the acquired data, we estimated a logistic regression model. As the results of our research show, the likelihood of campaign success is increased by the perception of equity crowdfunding as a tool enabling the acquisition of product and market knowledge, while using this form of financing mainly to obtain funds adversely affects the likelihood of campaign success. The results confirm that in Poland, as in other European countries, equity crowdfunding is no longer seen as a source of last-resort funding but is becoming more than just a fundraising tool. We recommend that entrepreneurs who plan to use this form of financing take advantage of the knowledge and experience of investors and treat equity crowdfunding as a strategic or first choice.*

Keywords: *Campaign success, non-financial motive, non-financial benefits, acquisition of product and market knowledge, alternative finance.*

JEL Classification: *G32, M13.*

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Introduction

Equity crowdfunding (ECF) is one of the alternative forms of financing that, in recent years, has been enjoying growing popularity, especially among startups. As pointed out by Ahlers et al. (2015), the essence of equity crowdfunding is to collect a certain amount of funds from many investors using an open call to sell a specified amount of equity or bond-like shares in a company on the Internet. This phenomenon involves three parties: 1) founders – the entrepreneurs pursuing equity investors; 2) funders – the crowd that is seeking investment opportunities; and 3) the platforms facilitating the transaction between the entrepreneurs and the investors (Mollick, 2013). Like other crowdfunding platforms, equity crowdfunding platforms are two-sided markets that match

founders with funders. These platforms operate based on the "all or nothing" model (enabling the entrepreneur to obtain funds only when at least 100% of the financial goal is achieved) or the "keep-it-all" model (enabling the entrepreneur to retain all the funds obtained regardless of their size) (Yasar, 2021). The ECF platforms that link fundraisers and backers operate in an electronic environment (online platforms) (Vismara, 2022; Vulkan et al., 2016). They disseminate information about the campaign but rarely verify the information disclosed in updates shared by entrepreneurs (Dorfleitner et al., 2018). ECF platforms are categorized as fintech. According to the Financial Stability Board (2022), fintech means technologically enabled innovation in financial services that could result in new business models, applications, processes or products with an associated material effect on financial markets and institutions and the provision of financial services.

In Poland, the ECF began in 2012 when the first campaign was conducted. We observed a dynamic market development for the first ten years, which slowed down in 2022. In 2021, the number of ECF campaigns in Poland reached 85, which constituted a 42% increase compared to 2020. Two hundred twenty-five campaigns were conducted between 2012 and 2021 (Association of Financial Enterprises in Poland, 2022). Significant changes have also been observed in the amount of capital accumulated through the ECF (from EUR 12,225 in 2012 to EUR 27.2 million in 2021; in all cases, the exchange rate at the end of the given year was used), with an increase of 4,868% between 2016 and 2021 (Duszczyk, 2022). The year 2022 was characterized by a significant slowdown in the ECF market in Poland. Only EUR 5.35 million was raised (while entrepreneurs sought to raise around EUR 21.2 million). The number of ECF campaigns conducted this year is only 47. Difficult for ECF in Poland was also another year in which only a limited number of companies decided to carry out a campaign – including, among others, Kombinat Konopny (the company provides easy access to high-quality hemp products), which raised EUR 1 million in less than three hours (Bełcik, 2023). According to experts, the reasons for such a significant slowdown in the ECF market compared to previous years are to be found in the economic slowdown, high inflation, and interest rates. The ECF market in this period was also significantly influenced by the fact that it was a period of critical changes related to Regulation on European Crowdfunding Service Providers – ECSP (Regulation on European crowdfunding service providers for business of 7 October 2020).

Legal regulations are among the factors determining crowdfunding development in a given country (Ande & Kavame Eroglu, 2021; Lazzaro & Noonan, 2021; Li, 2022). In Poland, no legal regulations directly related to crowdfunding activities existed in the first nine years of the ECF market. ECF platforms operated primarily based on the rules provided for in the Public offering act (Act on public offering, conditions for introducing financial instruments to an organized trading system and public companies of 29 July 2005) and the Trading act (Act on trading in financial instruments of 29 July 2005). As of November 2021, the implementation of changes resulting from enacting a new law on crowdfunding for business ventures implementing the ECSP began. In 2022, the limit on the value of a public offering not requiring a prospectus was increased from EUR 1 million to EUR 2.5 million. As of November 2023, the limit has been increased to EUR 5 million, allowing mature companies to increase their participation. Since 10 November 2023, the platforms' operations have been licensed and supervised. The introduced changes are intended to foster the development of this form of alternative financing.

As entrepreneurs try to raise funds from investors using the ECF, one of the fundamental issues related to the phenomenon is identifying factors enabling entrepreneurs to reach a specific amount of financial resources (financial goal), i.e., identification of success determinants. Knowing the determinants of a campaign's success is a crucial issue for entrepreneurs because, as Ralcheva and Roosenboom (2020) point out, failure in earlier campaigns can significantly impact subsequent attempts at funding through ECF campaigns. As the first feedback from the public on a company's business ideas, ECF generates a first impression. The authors proved that more than half of the companies that launched campaigns after failing in the first one failed to succeed and raise the set amount. In turn, campaign success attracts success with subsequent campaigns (Ralcheva & Roosenboom, 2020; Signori & Vismara, 2018; Vismara, 2018).

The success factors of the ECF campaign are already well recognized in the literature but have not previously been studied in the context of Poland. This article aims to fill the research gap in identifying the determinants of ECF success in Poland based on empirical data. As the ECF market develops, the attitude of entrepreneurs to this method of financing also changes over time. Ralcheva and Roosenboom (2020) indicated that in recent years, this form of funding has also been used by older and more stable companies with better access to external financing than startups, which proves that the equity crowdfunding market has already reached a certain level of maturity. Di Pietro et al. (2018) also confirmed that the companies exploiting the crowd network – to get input on products, strategies, and other market knowledge – are more effective. Therefore, we aimed to demonstrate whether and how entrepreneurs' conscious use of the non-financial benefits linked to ECF influences the campaign's success in Poland. We compare the results obtained with those obtained by researchers in other European countries. To this goal, we surveyed companies already using ECF to raise funds in Poland. We applied a logistic regression model for the study, as we could not use structural equation modeling (SEM) due to the sample size. Our results show that the likelihood of campaign success is increased by entrepreneurs' perception of ECF as a tool enabling the acquisition of product and market knowledge. Using this form of financing mainly to obtain funds adversely affects the likelihood of campaign success.

The article is structured as follows. Section 1 presents a literature review of ECF campaign success factors in selected countries. Based on the success determinants that emerged, we formulated the research hypotheses. Section 2 characterizes the research sample and discusses the research methodology, showing the construction of the PMK construct. Section 3 presents the results of the logistic regression model estimation, goodness of fit of the model, hypothesis testing, and discussion. The final section includes a discussion of key findings and conclusions, practical implications for companies that intend to use ECF in the future, and limitations and future directions.

1. Theoretical background and hypothesis development

There are many variations in content (selection of the determiners adopted for analysis), territory/geography (region analyzed), and methodology (the adopted research method) in the papers investigating the success factors of the ECF (Tab. 1).

Summarizing the data in Tab. 1, it is possible to distinguish three main groups of determinants affecting the success of ECF, which are presented in Fig. 1.

Tab. 1: Characteristics of selected studies on ECF success factors – Part 1

Authors	Factors adopted for analysis	Geographical area	Research method
Ahlers et al. (2015)	▪ Human capital ▪ Social capital ▪ Intellectual capital ▪ Equity share ▪ Financial projections ▪ Additional control variables to account for factors that may either influence the funding process or are related to a venture's future performance	Australia	Regression analysis
Lukkarinen et al. (2016)	▪ Campaign characteristics ▪ Attracting traditional early-stage company financing	Finland	Regression analysis
Vismara (2016)	▪ Equity retention and social network	UK	Regression analysis

Tab. 1: Characteristics of selected studies on ECF success factors – Part 2

Authors	Factors adopted for analysis	Geographical area	Research method
Di Pietro et al. (2018)	▪ Non-financial benefits for entrepreneurs	Six European equity crowdfunding platforms: Crowdcube and Seedrs in the United Kingdom, Symbid in the Netherlands, FoundedByMe in Sweden, Wiseed in France, and Seedmatch in Germany (60 European startups)	Qualitative study
Estrin et al. (2018)	▪ Reasons for bypassing institutional funding models (banks and VCs) ▪ Reasons for using ECF for fundraising ▪ Reasons for avoiding ECF for fundraising	UK	Qualitative study (Gioia methodology)
Rossi and Vismara (2018)	▪ Pre-launch services ▪ Ongoing campaign services ▪ Post-campaign services ▪ Control variables: the platform's year of launch and the type of business model adopted	Italy, France, UK, Germany	Regression analysis
Piva and Rossi-Lamastra (2018)	▪ Human capital signals	Italy	Probit model
Ralcheva and Roosenboom (2020)	▪ Campaign characteristics ▪ Company characteristics ▪ Characteristics relating to the director ▪ Team and its composition	UK	Logistic regression models; parsimonious forecasting models
Troise and Tani (2020)	▪ Entrepreneurial characteristics ▪ Entrepreneurial motivations ▪ Entrepreneurial behaviors	Italy	PLS-SEM; SEM structural equation modeling
Di Pietro (2021)	▪ Financial and non-financial benefits for entrepreneurs	UK	Qualitative study

Source: own (based on a literature review)

Entrepreneurs' motives can be divided into financial and non-financial ones. Initially, the financial motive was the dominant motive, as the ECF was perceived by companies mainly as a way to quickly raise capital that cannot be obtained from other (mainly traditional) sources. In addition, the successful campaign was seen as an opportunity to get capital from other sources in the future (Hornuf et al., 2018; Signori & Vismara, 2018). As Di Pietro (2021) emphasizes, many previous studies prove that the commonly accepted view was that entrepreneurs

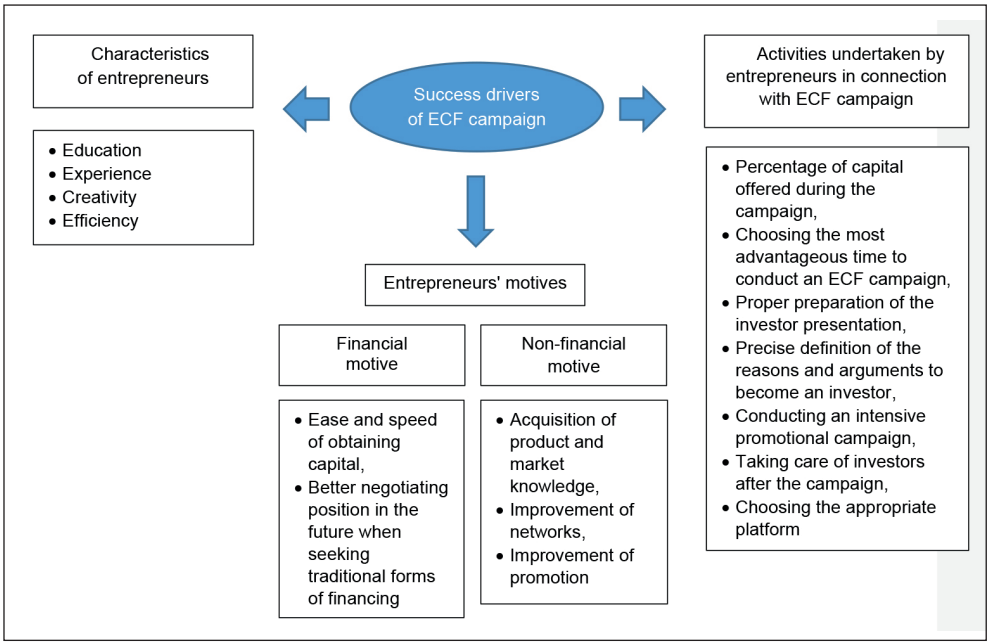

Fig. 1: Success drivers of ECF campaign

Source: Pauka et al. (2023)

perceive crowdfunding as the last resort and only try this form of financing when other sources of funding are not available (Blaseg et al., 2021; Walthoff-Borm et al., 2018). Over time, however, entrepreneurs have become increasingly aware of the wide range of non-financial benefits. The authors of many studies emphasize that ECF is more than a fundraising tool. They analyze a comprehensive catalog of non-financial benefits (Di Pietro, 2021; Di Pietro et al., 2018; Estrin et al., 2018; Troise & Tani, 2020; Wald et al., 2019; Walthoff-Borm et al., 2018). More recent research indicates that ECF can be a strategic choice for companies, an entrepreneur's first choice (Coakley et al., 2022; Cumming et al., 2021; Junge et al., 2022; Stevenson et al., 2022).

Among the benefits of a non-financial nature, the acquisition of product and market knowledge (PMK) deserves special attention. Many authors emphasize the unique role of ECF, which enables testing products, gaining knowledge, and getting feedback, as well as several other benefits that help the company to grow and develop (Belleflamme et al., 2014; Di Pietro et al., 2018; Estrin et al., 2018; Troise & Tani, 2020). Di Pietro's research (2021), carried out based on data from 38 companies that fundraised via ECF in the UK, proved that the opportunity to validate business market potential is one of the primary motivations for using the ECF. Similarly, Barney (2001) and Meyer (2019) suggest that entrepreneurs should use ECF to gain access to various valuable resources, using this form of capital raising to leverage the knowledge and experience of the crowd. Summarizing the investors' importance for entrepreneurs involved in an ECF, Di Pietro et al. (2018) point out two key areas companies can benefit: knowledge and network exploitation. The interpretation of both issues is presented in Fig. 2.

Taking into account the change in ECF perception by entrepreneurs, i.e., the transition from the last resort financing to the conscious use of non-financial benefits, we decided to adopt the following hypotheses:

H1: Success of an ECF campaign is less likely with the companies that perceive fundraising (FM) as the campaign's primary goal.

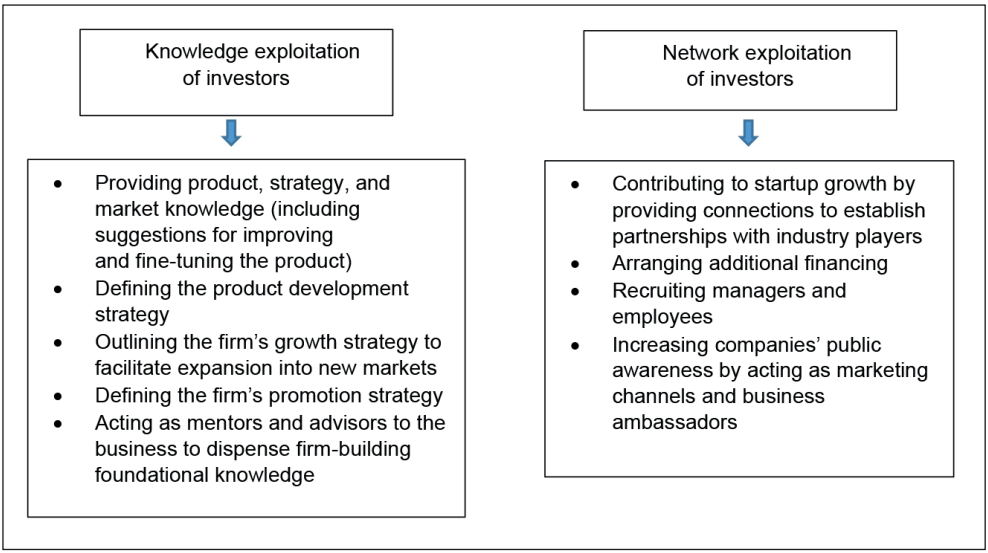

Fig. 2: **The role of investors in the ECF**

Source: Di Pietro et al. (2018)

H2: Success of an ECF campaign is more likely with the companies that perceive the acquisition of product and market knowledge (PMK) as the campaign's primary goal.

According to the literature, entrepreneurs' behaviors related to an ECF campaign are another critical group of determinants of the ECF's success. Based on the signaling theory (Spence, 1978), the characteristics of a campaign and the way it is conducted, including the method of communication with potential investors, generate meaningful signals, thus affecting the perception of the project/company by potential investors (Ahlers et al., 2015; Piva & Rossi-Lamastra, 2018; Troise & Tani, 2020; Vismara, 2016).

The scope of information used in campaigns is extensive (Polzin et al., 2018). There is information about the project or company, the project/company objectives, the person or organization behind the project/company, previous projects, people or organization behind them, as well as information on the financial plan of the project/company and the associated risks (Ahlers et al., 2015; Bernstein et al., 2017; Cholakova & Clarysse, 2015; Hornuf & Schwienbacher, 2015; Polzin et al., 2018). Business milestones are also presented (Johan & Zhang, 2022). Entrepreneurs communicate with stakeholders through videos, releases on social media, and investor relations channels (Moritz et al., 2015). Scientists have also identified some components of communication that positively impact a campaign's success, such as language simplicity and the number of updates (Block et al., 2018). Polzin et al. (2018) proved that funders from the in-crowd (who have strong or weak interpersonal ties with the project creator) attach more importance to information on the project owner and the projects previously owned by him than the investors who do not have such connections (out-crowd).

Activities carried out by entrepreneurs during an ECF campaign affect the understanding of the company's objectives and mission as well as of the concept of a given product/project and thus translate into ECF performance, i.e., attracting a sufficient number of investors to ensure that the necessary amount of capital is raised. Taking into account the efforts made by companies to communicate effectively with potential investors, we formulated the following hypothesis:

H3: An ECF campaign success is more likely with the companies that perceive precise

formulation of the reasons and arguments to become an investor (backer) as an essential factor in campaign preparation.

In ECF, investors are not solely the providers of capital. This form of financing allows for a loyal customer base, a large community of people passionate about the business who assist in the brand's development (Di Pietro, 2021; Estrin et al., 2018; Troise & Tani, 2020). That is because ECF enables the transformation of customers into investors. Entrepreneurs wishing to attract investors ready to support their idea with ECF should, therefore, remember that while communicating with potential investors, they should generate clear signals to confirm the presence of their desired values in the project.

Winning the trust of future investors is a fundamental issue. As Hornuf and Schwienbacher (2015) demonstrated, while deciding to get engaged in a project, investors look at the information provided by the project owners as well as at the investment behaviors and comments from other investors. A crowdfunding campaign's success may be determined not only by the activities carried out during the campaign but also by the level of care offered to investors after the campaign's end to maintain the company's credibility and create/maintain its trustworthiness. Hence, we formulated the final hypothesis as follows:

H4: An ECF campaign success is more likely with those companies that perceive post-campaign investor care (to maintain the company's credibility and trustworthiness) as an activity crucial for using ECF as a funding source.

Fig. 3. presents a conceptual framework for the research model.

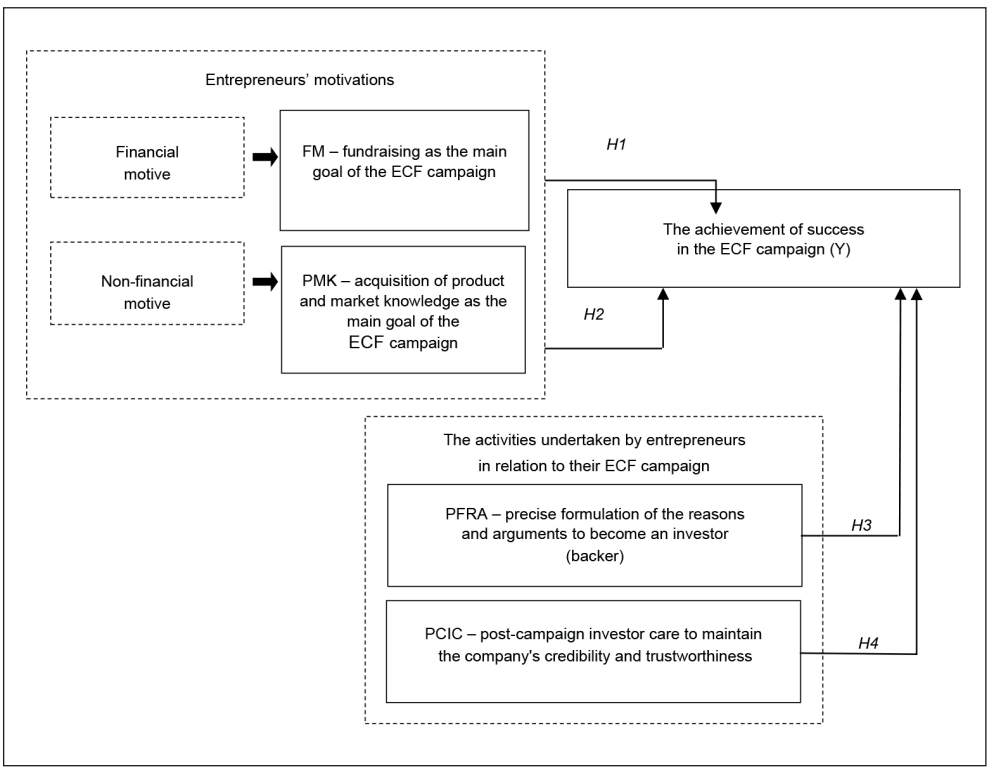

Fig. 3: Conceptual framework

Source: own

2. Research methodology

The variables for the model were selected on the basis of a survey on the determinants of ECF campaign success. We conducted the survey between 24 September 2021 and 24 January 2022 in cooperation with Biostat Research and Development Center (Centrum Badawczo-Rozwojowe Biostat Sp. z o.o.) as well as Beesfund, Crowdway and FindFunds platforms. The survey was addressed to representatives of all active companies that had raised funds through equity crowdfunding by the time of the research (80 companies). Fifty-six firms accepted the invitation to participate in the survey. When contacting a company, CAWI was the method of first choice, only

Tab. 2: Companies that were successful and those that experienced failure

Characteristic	Total (49 companies)	Successful (28 companies)	Unsuccessful (21 companies)
Legal form			
Joint-stock company	40	21	19
Limited joint-stock company	1	1	0
Private limited company	8	6	2
Company lifetime			
Up to one year	5	4	1
More than one year	44	24	20
Industry			
Food	10	5	5
Gaming	7	7	0
IT	4	3	1
Financial services	4	2	2
Hemp	3	3	0
Energy	3	2	1
Biotechnology	2	0	2
Hospitality	2	1	1
Medical	2	1	1
Clothing	2	0	2
Health and wellness	2	2	0
Drones	1	0	1
Film	1	0	1
Space exploration	1	1	0
Automotive	1	0	1
Sports	1	0	1
Communication and multimedia	1	1	0
Websites	1	0	1
Airlines and aviation	1	0	1

Source: own

if the attempt to obtain data by this method was unsuccessful, CATI was used. For 22 companies, the survey was carried out using the CATI (computer-assisted telephone interviewing), while the remaining used the CAWI (computer-assisted web interviewing) method. Strict quality control was adopted for the subjects. Using Cook's distance measure, atypical cases affecting the loading of the regression equation coefficients were diagnosed and removed from the analysis. Finally, the logistic regression model estimation was based on data obtained from 49 firms.

Tab. 2 presents the characteristics of the research sample adopted for the analysis. In 2021, in Poland, as many as 15 out of 16 active crowdfunding platforms cooperated with companies on ECF issuances.

The platforms most frequently used by the companies covered by the study include Beesfund (38.77%) and Crowdway (24.49%). The highest percentage of successful ECF campaigns was recorded for the platforms of CrowdConnect (100%) and FindFunds (81.82%) (Fig. 4).

The survey questionnaire that provided the empirical data used in this article addressed all three main groups of determinants of ECF success listed in Fig. 1. Additionally, we added a fourth factor to the analysis and questionnaire: the success of the previous ECF campaign – in line with the concept that success attracts success (Ralcheva & Roosenboom, 2020; Signori & Vismara, 2018; Vismara, 2018). Finally, the variables that entered the model concerned two groups – entrepreneurs' motives and activities they undertook in connection with the ECF campaign. The unit of our research is a company that has launched a successful ECF campaign. Success is defined as reaching 100% or more of the campaign's financial target. The explanatory variable is the achievement of success in an ECF campaign. The survey results analysis shows that 57.14% of the companies surveyed have succeeded, and 42.86% have experienced failure.

Predictors include:

- FM – fundraising as the main goal of the ECF campaign;

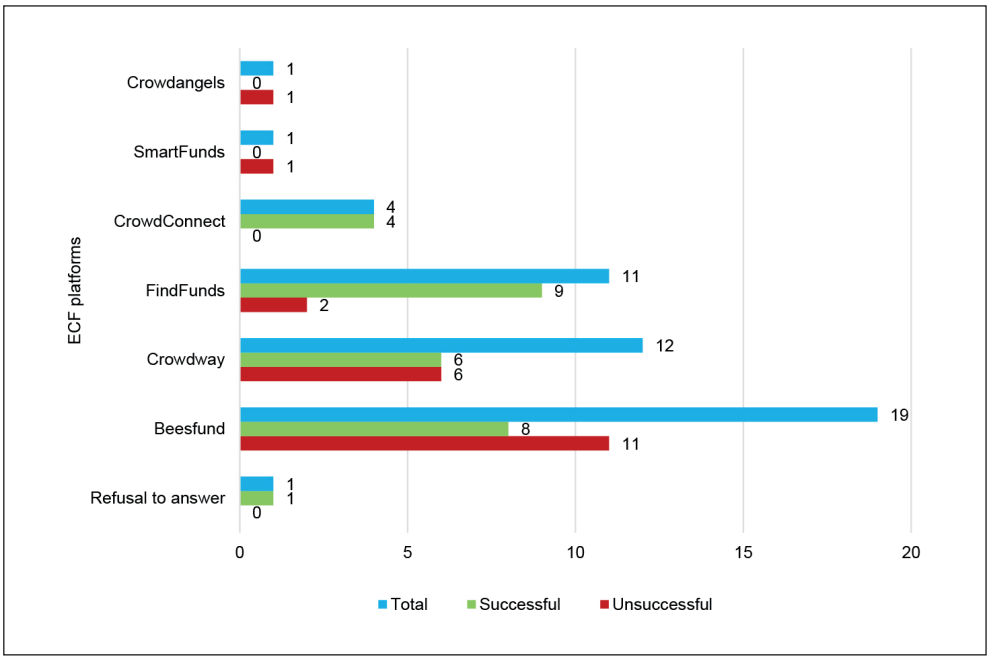

Fig. 4: ECF platforms used by the companies surveyed

Source: own

- PMK – acquisition of product and market knowledge as the main goal of the ECF campaign;
- PFRA – precise formulation of the reasons and arguments to become an investor (backer);
- PCIC – post-campaign investor care to maintain the company's credibility and trustworthiness.

To ensure the reliability and validity of the scale, we used mature scales in the existing literature to measure the PMK construct. In line with the contributions of previous studies (Di Pietro, 2021; Di Pietro et al., 2018; Estrin et al., 2018; Troise & Tani, 2020), the PMK was created based on responses obtained from respondents agreeing with statements presented in Tab. 3. Cronbach's alpha for the construct is 0.7. Cronbach's alpha coefficient is a measure of the internal consistency of a set of questions in a questionnaire. A coefficient of 0.7 means that it indicates that the questions used reliably measure the same construct.

Tab. 3: PMK construct

Statements	Respondents agreeing with the statement (%)
Market verification of the business credibility (external project evaluation) was an essential factor in selecting ECF as a source of financing.	59.18
ECF was perceived as an opportunity to find out very quickly if the market would accept the product (crowdfunding enables both the concept valuation against the assumed forecasts and an estimation of the market response to the products or services).	63.27
ECF made us recognize the need to manage the expectations of the community (investors) engaged in the project, which translates into continuous improvement of the project and increased investor confidence in its success.	71.43
The ECF campaign was perceived as an excellent opportunity to gain knowledge about the market and identify current market trends.	65.31

Source: own

In the project's assumptions, the authors specified that SEM would be the leading research method for identifying determinants determining the success of ECF campaigns in Poland. However, the relatively small research sample made structural equation modeling impossible.

3. Results and discussion

3.1 Results

The results of the logistic regression model estimation are presented in Tab. 4.

As the regression results presented in the table show, all variables are statistically significant. The goodness of model fit was verified using the following tests: likelihood ratio test, Hosmer-Lemeshow test, Cox-Snell R^2, and Nagelkerk R^2. G statistics for model deviance amounts to 44,355 and is statistically significant. The result of the Hosmer-Lemeshow test turned out to be statistically insignificant ($p > 0.05$). At the same time, the values of Cox-Snell R^2 and Nagelkerk R^2 are higher than 0, proving a good fit between the model and data. Thus, a good fit was confirmed, which indicates that the model provides a new explanation for the behavior of the dependent variable better than in the random model. Taking into account the results of logistic regression model estimation, Tab. 5 shows the results of hypothesis testing.

The model correctly classified 83.67% of the decision classes. In Tab. 6, the rows correspond to the predicted results and the columns represent the observed results (success – 1, failure – 0).

Tab. 4: Results of the logistic regression model estimation

Variables	B (regression coefficients)	SE (standard error)	OR (odds ratio)	Wald test	*p*
Constant	0.770	1.861	2.160	0.171	0.679
PFRA	–1.817*	0.857	0.163	4.495	0.034
PCIC	–3.967*	1.586	0.019	6.259	0.012
FM	–3.950**	1.364	0.019	8.389	0.004
PMK	0.475*	0.188	1.608	6.356	0.012
R^2 Coxa-Snella	0.369				
R^2 Nagelkerka	0.496				

Note: * $p < 0.05$; ** $p < 0.010$; *** $p < 0.001$.

Source: own

Tab. 5: Hypothesis testing

Hypothesis	Logistic regression results	Results of hypothesis testing
H1	The probability of success in an ECF campaign is lower by 98%, with companies that declared that obtaining funds had been the main objective of launching their ECF campaign.	The results of our study support the hypothesis.
H2	The probability of success in an ECF campaign is higher by nearly 61% with companies for which the acquisition of product and market knowledge was the most crucial objective of launching their ECF campaign.	The results of our study support the hypothesis.
H3	The probability of success in an ECF campaign is lower by nearly 84% with companies for which a precise definition of reasons and arguments to become an investor (backer) is essential, compared to those for which it is not.	The results of our study do not support this hypothesis.
H4	The probability of success in an ECF campaign is lower by 98%, with companies for which investors care after the campaign is vital to maintain the credibility and trustworthiness of the company, compared to those for which it is not.	The results of our study do not support this hypothesis.

Source: own

Tab. 6: Classification

Classification		Observed value		
		0	**1**	**Σ**
Predicted value	**0**	16	3	19
	1	5	25	30
	Σ	21	28	49

Source: own

The area under the ROC curve (AUC) is 0.865; therefore, it is greater than 0.5. The model classifies cases better than the random model.

3.2 Discussion

First, we proved that in Poland, the success of an ECF campaign is more likely in those companies that see the acquisition of product and market knowledge (PMK) as the main objective of ECF. At the same time, our research showed that those companies for which the main objective of using ECF is the acquisition of funds (FM) are less likely to succeed. These results are in line with the insights of Di Pietro et al. (2018), Estrin et al. (2018), Wald et al. (2019), Troise and Tani (2020), and Di Pietro (2021) that due to the wide range of possible benefits, ECF is more than financing tool. Our results highlight the unique role of ECF in acquiring product and market knowledge, thus confirming the results obtained by Belleflamme et al. (2014), Di Pietro et al. (2018), Estrin et al. (2018), and Troise and Tani (2020). Acting as mentors and advisors, investors contribute to the company's performance (most often start-ups). The role of backers in providing knowledge about the product, strategy and market, including suggestions for improving the product, defining the product development strategy, and contributing to the definition of the company's expansion strategy into new markets, cannot be overestimated. Our estimation of the logistic regression model carried out based on 49 companies in Poland confirms the conclusions of Di Pietro et al. (2018) drawn based on their analysis of six European equity crowdfunding platforms (Crowdcube and Seedrs in the United Kingdom, Symbid in the Netherlands, FoundedByMe in Sweden, Wiseed in France, and Seedmatch in Germany) that the more effective are those companies that use knowledge and involvement of funders to obtain feedback on products, strategies and other markets.

Second, taking into account the direction of influence of the two discussed determinants (FM and PMK) on the probability of success of ECF campaigns, our research for Poland confirms that a certain maturity of entrepreneurs and a growing awareness of the achievable benefits associated with this form of financing can already be observed in Poland. This finding for the Polish ECF market is in line with the observation made by Cummings et al. (2021), Ralcheva and Roosenboom (2020), Junge et al. (2022), Stevenson et al. (2022) or Coakley et al. (2022), who demonstrate that the perception of ECF has been changing recently, and the previously accepted judgment that ECF only benefits companies that have failed to raise funds from other sources has been losing importance.

Third, our research found that precise formulation of the reasons and arguments to become an investor (PFRA) and post-campaign investor care to maintain the company's credibility and trustworthiness (PCIC) reduce the chance of a successful ECF campaign. By using credible signals, entrepreneurs can convey positive information about the project and the company, reducing information asymmetry and allowing investors to better assess the quality of available investment opportunities (Ahlers et al., 2015; Ralcheva & Roosenboom, 2020). However, it depends on the investors' individual motivations, which information, declarations and actions of companies seeking to raise capital are considered. As mentioned earlier, the results of research conducted by Polzin et al. (2018), who compared the behaviors of in-crowd and out-crowd funders, proved that these groups are driven by different information and those who have interpersonal ties with the project owner (even if they are weak ones) are to a larger extent driven by information about the owners of the project and their previous projects. Therefore, these authors suggest that entrepreneurs should adjust the type of information to the recipient when preparing a campaign. Information addressed to potential in-crowd funders should focus on a detailed presentation of project owners and their previous projects and provide only summary information on the current project and its goals, as well as on financial planning and risks. In contrast, information targeted at the out-crowd funders should be developed differently and only briefly present personal information about project owners.

The results of our research show that the probability of success is not increased by attaching great importance to the precise formulation of the reasons and arguments why it is worth becoming an investor (PFRA) or post-campaign investor care (PCIC). The explanation for such results may be that most investors were mainly interested in other signals and other information, e.g., the information

about the project owners and their previous projects was more important to them. It may mean that most of the investors attracted by the companies in question had (strong or weak) interpersonal ties with the project owners. Such an explanation is justified by the research conducted by Vismara (2016), who claims that investors are more likely to engage in the ventures of people they know personally or associate with them through social networks.

Conclusions

Main findings. By examining ECF success factors in Poland based on empirical data, we fill a research gap in the existing literature. In addition, a review of the literature on ECF success factors shows that, in recent times, ECF is no longer perceived by entrepreneurs as a source of financing of last resort, but they appreciate the wide spectrum of non-financial benefits associated with this form of financing (including mainly the use of crowd potential). Our goal, therefore, was to demonstrate whether and how entrepreneurs' conscious use of the non-financial benefits associated with ECF affects the campaign's success in Poland. The results of our research confirm that both the motives of entrepreneurs, the goals they want to achieve by using ECF, and the actions they take in connection with the campaign have an impact on the success of the campaign and the raising of the necessary funds. Analysis of the results proves that the probability of success in an ECF campaign is:

- Lower by 98% with companies that declared that obtaining funds had been the main objective of launching their ECF campaign;
- Higher by nearly 61% with companies for which acquisition of product and market knowledge was the most important objective of launching their ECF campaign;
- Lower by nearly 84% with companies for which a precise definition of reasons and arguments to become an investor (backer) is important, compared to those for which it is not;
- Lower by 98% with companies for which investors care after the campaign is important to maintain the credibility and trustworthiness of the company, compared to those for which it is not.

Comparison of the results of our research and the results conducted by Cummings et al. (2021), Ralcheva and Roosenboom (2020), Junge et al. (2022), Stevenson et al. (2022) or Coakley et al. (2022) prove that both in Poland and other European countries, entrepreneurs use ECF not only to quickly obtain the needed funds but also consciously use a wide spectrum of non-financial benefits, including, above all, the potential that lies in the power of the crowd (backers). It clearly shows that in Poland, as in other European countries, companies do not reach for this form of financing only when other sources of financing are unavailable to them, but they recognize and appreciate the specificity of this form of financing.

Practical implications. Knowing the drivers of equity crowdfunding campaigns is vital for entrepreneurs who plan to take advantage of this form of financing. One of the objectives of business owners launching ECF campaigns is also to reach other sources of financing (professional investors or traditional sources of financing) after a successful campaign. As Brown et al. (2018), Butticè et al. (2020), and Ralcheva and Roosenboom (2020) point out, ECF is not limited to quick funding opportunities. A successful campaign also means a better chance of raising funds in the future – using ECF again, venture capital/angel investors, or traditional sources. Bearing in mind that success brings success (Ralcheva & Roosenboom, 2020; Signori & Vismara, 2018; Vismara, 2018), it can be concluded that concern for the proper realization of the ECF campaign affects not only the achievement of desired results but also for the company's future and its future access to financing. The results of our research may be helpful for companies that intend to use ECF in the future. We confirm the conclusion formulated by many authors highlighting ECF's broad potential for non-financial benefits, especially with regard to the acquisition of product and market knowledge, and claiming that ECF constitutes far more than a fundraising tool (Di Pietro, 2021; Di Pietro et al., 2018; Estrin et al., 2018; Troise & Tani, 2020; Wald et al., 2019; Walthoff-Borm et al., 2018). We recommend that entrepreneurs who plan to use this form of financing consider the wide range of benefits it brings to take full advantage of its potential (not limited to benefits of a financial nature). In addition, we recommend considering ECF as a strategic and first-choice tool. We suggest that business owners consciously take advantage of ECF, especially concerning crowd resources

(backers) – knowledge and network exploitation. Experts assume that after a significant slowdown in the development of the ECF market in Poland, which we observed starting in 2022, the changes introduced in the legal environment by the end of November 2023 will improve the situation in this market. Licensed and supervised by the Polish financial supervision authority platforms, as well as many regulations increasing investor protection (such as a reflection period for inexperienced investors), should have an impact on restoring the interest of investors whose activity in the ECF market from 2022 onward has significantly decreased (the number of investors fell by as much as 80% compared to 2021), resulting in their transfer to other markets (Association of Financial Enterprises in Poland, 2023).

Limitations and future directions. Our research is the first of this type for the Polish market. A limitation of the study is the relatively small number of entities that already have experience raising funds using ECF in Poland. It seems worth repeating the survey in a few years, which will allow not only to enlarge the research sample but also to compare the results with those described in this article. A later study will also be valuable because Poland is still changing the legal environment related to ECF. In this way, it will be possible to broaden the analysis by also showing whether and how changes in legal regulations have affected the use and perception of ECF by entrepreneurs in Poland. Furthermore, more extensive research sample will allow the introduction of new research methods (e.g., enable the use of SEM). It would also seem valuable to expand the catalog of success factors adopted for the study and select additional countries to compare results obtained for the Polish ECF market. It could also be useful to look at whether and how the determining factors of success differ depending on the company's industry, size, or age.

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A composite index to measure sustainability of supply chain management in construction companies

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Abstract: *Companies in the construction sector are increasingly aware of the importance and challenges of sustainability. In recent years, construction companies have introduced some sustainability initiatives and have embraced the concept of sustainability indicators. However, measuring a company's performance on a wide range of sustainability indicators is challenging. Integration of supply chain sustainability indicators is required. This article presents a methodology for easily consolidating existing supply chain indicators into a single analysis that requires minimal resources. First, the list of 38 sustainability indicators of the supply chain was defined and divided into 7 sustainability groups. The experts were then asked to rank the sustainability groups and the supply chain sustainability indicators within each group according to their importance using the rank sum weighting method. The survey questionnaire was distributed to the respondents via paper or email to 24 academics and top/middle managers of construction companies. Global normalized weights were employed to determine the final indicator rankings. For normalization, target values were suggested for each indicator. Finally, a composite sustainability index for a construction company's supply chain was developed. The developed composite sustainability index provides a global view of sustainable supply chain management in construction companies, allowing supply chain indicators to be related to their objectives. The developed composite index can be used by supply chain managers in construction companies to assess their organization's contribution to supply chain sustainability.*

Keywords: *Sustainability index, supply chain management, construction supply chain, index development, sustainable construction.*

JEL Classification: *L74, C43, C44.*

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Introduction

Increasing demands for sustainability are significantly impacting the construction sector. Therefore, it is crucial to incorporate assessments of sustainable supply chain management and implement an index to measure sustainable progress. Experienced assessors typically conduct construction supply chain management

(SCM) assessments, considering economic, physical, social, and geographic factors. Although there are some relevant studies and articles in this field of study, the development of a thorough, impartial, trustworthy, and useful evaluation and indexing model for sustainability aspects in construction companies has not been the subject of much, if any, extensive and systematic research. This study develops a benchmark evaluation model to objectively assess the success of sustainability initiatives in the supply chain of construction companies, utilizing a questionnaire survey approach.

Recently, construction companies started to apply sustainable initiatives such as sustainable SCM (Farooque et al., 2019) and adopted the concept of sustainability indicators (Ebolor et al., 2022; Salah et al., 2023), but the question of how to measure sustainability most efficiently remains unanswered. A new set of concepts, regulations, tools, inventions, and procedures are needed to accomplish the significant changes necessary in the construction industry and start to evaluate sustainability patterns for successful development (Van Horen et al., 2018; Zhang & Song, 2022).

Integrating sustainable development techniques throughout the whole supply chain (SC) lifecycle is the goal of sustainable supply chain management (Ecer & Pamucar, 2020). To accomplish management optimization of the entire SC lifespan with SSCM, better information exchange and precise assessment are required (Alkhudary et al., 2020; Tönnissen & Teuteberg, 2020). Finding new methods to measure the sustainability index for the construction sector generally significantly improves a construction company's performance (Chen et al., 2020). Additionally, applying a practical indexing system can help construction companies efficiently evaluate sustainability practices in the supply chains, contributing to a company's sustainable performance (Luthra et al., 2017).

The purpose of the research was to determine the possible benefits of evaluating and managing sustainability practices in the supply chain of construction companies through the use of sustainability indicators (SI). The composite sustainability performance index proposed in this article consolidates numerous indicators, simplifying complex and diverse data. This simplifies benchmarking and interpretation of sustainability performance, empowering construction companies to make informed decisions on sustainable supply chain management.

This paper is structured as follows: Section 1 presents the research framework of this study through theoretical analysis, drawing on the existing literature on challenges within sustainable supply chains in construction companies. Section 2 introduces the methodology employed in the study. Section 3 describes the results and presents a discussion. The final section discusses the research findings, limitations, and future research directions.

1. Theoretical background

Although sustainability is frequently used, advancements in construction companies are only slowly recognized (Masood et al., 2022). Effective management of relationships and interaction methods between construction companies, as evidenced by research from SCM scholars (Amiri et al., 2021; Mentzer et al., 2001), can facilitate the implementation of both local and comprehensive supply chains. The use of SSCM in construction companies reduces the impact on the environment, reduces the risk of failure, and increases its competitiveness (Studer & De Brito Mello, 2021; Suhi et al., 2019). While indicators and critical components have long been recognized as essential for sustainable initiatives (Gunnarsdóttir et al., 2021), only a few studies have explored using an indexing system to comprehensively assess sustainability achievements. Stanitsas et al. (2021) argue that there is still a gap in the literature concerning a comprehensive methodology and classification of sustainability indicators that contribute to sustainable project management in construction companies. Despite efforts to categorize indicators within the triple bottom line (TBL) framework, a lack of comprehensive sustainability assessments remains a challenge in supply chains (Chang et al., 2018). As the TBL scenario is essential for holistic sustainability evaluation (Usubiaga-Liaño & Ekins, 2021), this research proposes that focusing on targeted and categorized indicators can significantly improve the assessment of the sustainability performance of construction companies. In addition, there is growing global concern about the depletion of natural resources, environmental degradation and the increasing amount of waste generated by the linear economic model. To address these challenges, the concept of the circular economy

(CE) has gained traction as a more sustainable alternative to the traditional linear economic model. The construction sector significantly impacts the environment through its resource and energy consumption, as well as its waste production. CE, a new paradigm, can significantly improve the sustainability of this sector (Gasparri et al., 2023; Norouzi et al., 2021). In the construction sector, the CE involves using resources and materials to minimise waste and maximise their value. This approach includes the sustainable use of resources, such as designing buildings for easy disassembly and reuse of materials. Incorporating CE principles into construction SCM can bring significant benefits to both business and the environment.

Only a very small number of studies have focused extensively on the sustainability context of evaluation and indexation in construction supply chain management (Dobrovolskienė et al., 2017). Despite increasing understanding among experts on sustainability indicators, the issue of supplier selection was underlined as important in sustainable project management.

Understanding essential sustainability indicators is necessary to handle concerns related to SSCM in construction companies (Pade et al., 2008). The concept "indicator" does not correspond to a single defined and very exact idea, it also means a gauge or meter of a specified kind (Reid & Rout, 2020). The concept of indicators in the literature is ambiguous and inconsistent. Moldan and Dahl (2007) contend that not all groups of indicators are equally precise and quantitative. Jollands (2006) states that an indicator is, at its core, a sign; a statement that demands interpretation. According to Moldan and Dahl (2007), there are four types of indicators: indices, simple indicators, aggregate indicators, and composite indicators. Recognizing the multifaceted nature of sustainability indicators, this study proposes an index system adapted to assess the sustainability of a construction company's supply chain.

There are several frameworks for classifying sustainability evaluation techniques. For example, Gu and Wang (2022) categorize them as indicators, product-level assessment tools, project-level assessment tools, and sectoral/national assessment tools. The following categories also apply to sustainability assessment techniques. According to Suhi et al. (2019), and Dobrovolskienė and Tamošiūnienė (2016), there are three types of assessment methods: (1) indices, which can be integrated or non-integrated; (2) product-related assessment methods that concentrate on the material/energy flows of a product, good, or service from a lifecycle point of view; and (3) integrated assessment methods. As a result, classification can take many different forms, depending on how sustainability indicators are created and on what scale they are aggregated.

The assignment of weights to indicators is a crucial step in the quantitative evaluation of multiple criteria. Each indicator that characterizes the research object has a varying impact on the objective being considered (Mahat et al., 2021). Therefore, determining the significance of indicators, i.e., their weights, is essential. Various methods have been proposed in academic literature, broadly categorized into three approaches: subjective, objective, and integrated. The subjective assessment methods, where experts determine the weights of indicators, is the most commonly used approach (Biggeri & Ferrone, 2021), e.g., step-wise weight assessment ratio analysis (SWARA) (Kersuliene et al., 2010), decision-making trial and evaluation laboratory (DEMATEL) (Liu & Liu, 2022; Travisco et al., 2023), best worst method (BWM) (Moktadir et al., 2021; Soares et al., 2022), etc. Objective methods primarily focus on statistically evaluating data derived from the decision matrix, e.g., entropy (Hwang & Yoon, 1981), principal component analysis (Croux et al., 2013), and simultaneous evaluation of criteria and alternatives (SECA) (Keshavarz-Ghorabaee et al., 2018). Integrated methods ascertain the weights of the criteria by incorporating both subjective and objective information, for instance, opinion weight criteria method (OWCM; Mandil et al., 2024), (OWCM) (Mandil et al., 2024), full consistency method (FUCOM) (Fazlollahtabar et al., 2019). There is no single "best" weighting method. Each method comes with its own set of advantages and drawbacks. The precision and values of the weights depend on the chosen assessment method. Regardless of the method used, the assessment logic remains the same: the most important indicator (i^{th}) will have the highest weight (ω_i), and the sum of all weights should be equal (Podvezko & Podviezko, 2014).

According to López-Penabad et al. (2022), there are six steps involved in creating

a composite index: (1) theoretical framework, which should be multidimensional and stakeholder-oriented; (2) indicator selection; (3) exploratory analysis of indicators, which covers the indicator distribution, type of indicator, missing data, and outliers; (4) multivariate analysis, which assesses the suitability of the data set and allows a better understanding of methodological choices; (5) normalization, weighting, and aggregation of partial performances; and (6) the analysis of uncertainty and sensitivity of the results for the development of composite index.

Gu and Wang (2022) measured sustainable entrepreneurship using three indicators: innovative spirit, entrepreneurial spirit, and decision-making spirit. They also created a new time-varying index of sustainable entrepreneurship using a time-varying coefficient state-space equation model. This research examines the influence of sustainable entrepreneurship on Chinese regional economic growth using the new time-varying index and examines the role of technical R&D and financial intermediary development in the influence path. The composite sustainability index of a project (CSIP) was introduced by Dobrovolskienė and Tamošiūnienė (2016). To determine and prioritize the most crucial sustainability requirements, the expert survey was used. Using multi-criteria decision-making techniques, the index was created. The findings of the pilot study demonstrated a novel contribution by describing a method for evaluating a business project in the construction sector. López-Penabad et al. (2022) proposed a composite index based on the benefit of the doubt methodology to create a sustainable development index for rural municipalities. This index comprises four dimensions: economic, demographic, social, and environmental. They compare the empirical data with results obtained using alternative weighting methods: common weights, super efficiency, and geometric mean and logistic normalization models. The most well-known multi-criteria decision-making (MCDM) techniques such as SAW, COPRAS, TOPSIS, VIKOR, and MIVES were applied by Sánchez-Garrido et al. (2022) to derive the lifecycle performance of each design into a single sustainability score. Since there is disagreement over the most effective MCDM method for sustainability evaluation, a global structural sustainability index (GSSI) is provided here that combines and weights the aforementioned metrics to help with the analysis of the findings. The findings demonstrate that taking into account the three facets of sustainability results in well-balanced designs, which need not be generated from each one-dimensional life cycle approach. A concept developed for a case study in a manufacturing company on the return process was employed by Oliveira et al. (2019) to validate the methodology for constructing a composite indicator for SC processes. This indicator represents the weighted average of several measurements taken from the same process to assess overall performance in terms of effectiveness and efficiency. The study found that combining business intelligence tools with composite indicators provides a more comprehensive picture of process performance, facilitating easier root cause analysis.

By conducting a cross-sectional survey among 200 Ghanaian construction industry professionals, Ayarkwa et al. (2022) aimed to provide an empirical analysis of challenges and mitigation strategies to improve project management teams to adopt sustainable building processes. To improve the preparedness of project management teams for sustainable building processes, survey data was analyzed using descriptive statistics and relative relevance index rankings. As a result, a conceptual model was created. Kaldas et al. (2021) presented a newly developed framework for the sustainability assessment of manufacturing organizations due to the lack of a comprehensive framework for enterprise level sustainability assessment of manufacturing companies, making sustainability assessment time consuming to implement. In their study, a composite sustainability score was introduced that incorporates the 6R principle, the entire life cycle, and the TBL approach. The methodology consists of five basic steps: choosing the appropriate indicators, gathering data, normalizing those data, applying the fuzzy analytic hierarchy process to weigh the indicators found, and finally aggregating that data to determine the sustainability index.

Since in the most recent studies, the problem was underlined that the present methodologies and tools are not effective enough, inadequately secure, and unreliable, some steps must be taken to optimize sustainability assessment in construction SCM to meet the growing needs of clients and contractors

(Yan et al., 2019). To create a proactive and predictive sustainability evaluation mechanism in the construction SC, there is a need to concentrate on the decision-making based indexing model with operational efficiency.

2. Research methodology – The steps in developing the composite sustainability index for SCM in construction companies

Composite indexes that compare company performance are recognized as useful tools for setting priorities and benchmarking or monitoring performance. Gasparatos et al. (2008) defined the composite indicator as an aggregation of different indicators according to a well-developed and pre-determined methodology. Various methodologies are employed to construct composite indicators. Ideally, the composite indicator should measure multidimensional concepts that cannot be captured by a single indicator, for example, competitiveness, sustainability, performance, and profitability.

Based on previous research, we present the methodology used to develop the composite index. The methodology comprises the following steps:

1. Development of the theoretical framework;
2. Identification and selection of indicators;
3. Grouping of indicators and validation of their importance to construction companies;
4. Weighting of indicators;
5. Normalization of indicators;
6. Creating the composite index to measure the sustainability of an SCM in construction companies.

A thorough analysis of the literature on sustainability indicators and sustainability measurements in the construction sector resulted in the formulation of a conceptual framework with various indicators to assess the significance of successful sustainability initiatives in construction companies. The list of 38 SC sustainability indicators was divided into 7 sustainability groups: legal, physical, political, technological, economic, ecological, and social (Cataldo et al., 2021; Cataldo et al., 2022). Construction industry practitioners and academics from Lithuania and Northern Italy participated in a questionnaire survey to create an indexing system to evaluate the sustainability practices of the construction supply chain of construction companies. The structured interviews in this article were conducted according to Tura et al. (2019) guidelines for the interview planning strategy. The results of the systematic review process on sustainability indicators were confirmed using interviews as a means of collecting data from experts. The main objective of the interview was to determine whether the conclusions of the literature study on the indicators applied by SSCM in construction are confirmed by experts in the construction industry.

Determining the weight of the indicators is an important process for assessing the impact of the indicators on the decision or situation being assessed. Indicator weights can be determined using a variety of methods, depending on the specific assessment or decision model, e.g., methods derived from statistical models, such as factor analysis, data envelopment analysis, and unobserved components models, or from participatory methods such as budget allocation processes, analytic hierarchy processes, and conjoint analysis (Zhou et al., 2012). Most of the currently known and widely used methods for weighting indicators are based on expert judgement. The calculated indicators weights can be used in a multi-criteria evaluation if the experts' ratings are non-contradictory, i.e., the opinions are shown to be statistically consistent.

One of the approaches to variable weight determination is the rank sum weight method. This is one of the simplest approaches to assign criteria weights (Odu, 2019). The rank-sum-weight method is used for weighing of attributes with respect to each other for decision making problem. Firstly, attributes are identified. Then, the rank ordering of the attributes in the attribute set are decided. From this information, the weight for the given attribute is determined (Krishna et al., 2022). In our case, the indicators (groups) were ranked by experts from most important (i = 1) to least important ($i = n$). Therefore, e_{ik} denotes the rank proposed by k^{th} expert for i^{th} indicator (i = 1, ..., n; k = 1, ..., m), here n – number of indicators, m – number of experts. Then the set of expert evaluation is a matrix $E = \|e_{ik}\|$.

To assign weights in descending order of ranks, we need to rearrange the expert rankings. In this way, the best rank (first) would be assigned the lowest value. For this purpose, each indicator's ranking was transformed into the indicator's score based on the following equation (Stillwell et al., 1981):

$$r_{ik} = n + 1 - e_{ik} \quad (1)$$

After completing the transformation procedure, the level of agreement on the survey was measured using Kendall's coefficient of concordance (*W*). Additionally, Kendall's *W* can be calculated for both the initial and transformed indicators' ratings, resulting in the same value. The basis of the calculation is the sum of the ranks R_i *of* each *i* indicator concerning all experts (Equation (2)). In other words, the sum of the squares of the values R_i in deviation from the average rank $\overline{R}$ (Equation (3)), denoted by *S* (Equation (4)).

The sum of the ranks, R_i, is defined as:

$$R_i = \sum_{k=1}^{m} r_{ik} \tag{2}$$

An average rank, $\overline{R}$, is defined as:

$$\overline{R} = \frac{\sum_{i=1}^{n} R_i}{n} = \frac{\sum_{i=1}^{n}\sum_{k=1}^{m} r_{ik}}{n} \tag{3}$$

where: r_{ik} – *k* expert's indicator *i* evaluation ($k = 1, \ldots, m$); *m* – number of the experts; *n* – number of indicators.

The sum of squared deviations, *S*, is defined as:

$$S = \sum_{i=1}^{n} (R_i - \overline{R})^2 \tag{4}$$

Kendall's *W* is defined as:

$$W = \frac{12S}{m^2(n^3 - n)} \tag{5}$$

where: *S* – the sum of squared deviations.

If the test statistic *W* is 1, then all the judges or survey respondents have been unanimous, and each judge or respondent has assigned the same order to the list of objects or concerns. If *W* is 0, then there is no overall trend of agreement among the respondents, and their responses may be regarded as essentially random. Intermediate values of *W* indicate a greater or lesser degree of unanimity among the various judges or respondents.

The significance of the concordance coefficient is defined as:

$$x^2 = \frac{12S}{mn(n+1)} \tag{6}$$

The chi-square value must be greater than $\chi^2_{\alpha,\upsilon}$, which depends on the number of degrees of freedom and the chosen significance level, then considered the opinion of experts agreed. Otherwise, the $\chi^2 > \chi^2_{\alpha,\upsilon}$ states that the unmatched experts' opinions.

The sustainability group weight is determined using the rank sum method (Podvezko & Podviezko, 2014; Stillwell et al., 1981):

$$w_i = \frac{\sum_{k=1}^{m}(n+1-e_{ik})}{\sum_{i=1}^{n}\sum_{k=1}^{m}(n+1-e_{ik})} = \frac{\sum_{k=1}^{m} r_{ik}}{\sum_{i=1}^{n}\sum_{k=1}^{m} r_{ik}} \tag{7}$$

To account for variations in the number of indicators among sustainability groups, the weight of each indicator is calculated based on its respective group. This is achieved by normalizing the weight of each indicator (Equation (7)) through division by the average weight of the group's indicators $\overline{w^{group}}$. The result is the individual weight w_i^{ind} calculated using the following formula:

$$w_i^{ind} = {}^{w_i}/_{\overline{w^{group}}} \tag{8}$$

Now, if we have *x* sustainability indicators in a group, the sum of the individual weights within a group will also equal *x*.

The composite index should account for the weight of the indicators, since some may have a greater influence on the result than others. Therefore, before the data is aggregated, various weights should be allocated based on the significance of each sustainability indicator.

As indicators can be expressed in different units of measurement, it is necessary to normalize them to make them comparable. Furthermore, since different indicators serve different purposes, it is important that an improvement in each indicator also mean an equivalent improvement in the composite indicator. Several normalization methods exist (Mazziotta & Pareto, 2022; Nardo et al., 2005; Pollesch & Dale, 2016): ranking, standardization (or *z*-score), min-max, distance to a reference, categorical scale, indicators above or below the mean, cyclical indicators, the balance of opinions, percentage of annual differences

over consecutive years. The choice depends on the context of the specific analysis or decision, and it is important to perform a consistent analysis of the data to choose the appropriate normalization method.

The final step is aggregation and weighting of all inputs, according to their importance for the final calculation.

3. Results and discussion

3.1 Selection of the respondents for the survey

Selecting qualified experts for surveys is crucial to ensure accurate and reliable information. Their professionalism and analytical skills help avoid mistakes and provide a deeper understanding of the area surveyed. An intentional method was used to choose this group of specialists because the information requested calls for in-depth understanding and solid expertise in SC sustainability practices used in construction companies (Yeung et al., 2023). The study selection criteria were developed to determine the qualifications of potential participants. The first criterion requires extensive experience working on construction projects in Lithuania or Northern Italy, or significant research experience as an academic researcher on sustainable construction or related topics. The second criterion requires experts to have direct participation in the supply chain management of construction projects, recently or currently. The most valuable comments and responses were only considered to be solicited from practitioners and academics who met the aforementioned selection criteria.

For this study, 24 academics and practitioners were invited to participate. Their expertise spans a broad spectrum of academic scholars and members of top and middle management in construction companies in Northern Italy and Lithuania (Tab. 1). It is obvious from Tab. 1 that around 17% of respondents were from the field of ecological house design and construction, as well as another 17% were academics.

Tab. 1 and Tab. 2 display the demographic information of the survey participants.

Tab. 2 provides information on the profile of the respondents. It can be seen that the vast majority of experts (83.3%) who participated in the survey were male (as many as 20 out of 24), and the average age of the respondents was between 30 and 49 years old.

Tab. 1: Work fields of the respondents

No.	Field of work	Job position	Number of respondents
1	Building materials	Industrial manager, engineer	2
2	Removal of construction waste	Operations manager	1
3	Construction logistics	Logistics project manager, administrator	2
4	Solar energy	Project manager	1
5	Renewable technologies	Owner, renewable technology engineer	2
6	Constructional design	Designer, environmental engineer	2
7	Academia	Professor, researcher	4
8	Eco-house design and construction	Builder and designer of eco-homes	4
9	Modular homes	Engineer, project manager	2
10	The infrastructure of steel construction	Construction project manager	1
11	Green construction and passive homes	Engineer, worker	1
12	Architecture	Designer, architect	2

Source: own

Tab. 2: Profile of the respondents

Profile of the respondent	Classification	Total amount	Percentage (%)
Age (years)	20–29	3	12.5
	30–39	8	33.3
	40–49	7	29.2
	≥50	6	25.0
Gender	Male	20	83.3
	Female	4	16.7
Education	Secondary	1	4.2
	Higher	23	95.8
Number of employers in the company (people)	1–9	6	25.0
	10–19	13	54.2
	50–249	3	12.5
	≥250	2	8.3
Experience in the field (years)	Less than 5	1	4.2
	5–10	3	12.5
	10–15	11	45.8
	More than 15	9	37.5

Source: own

Most of the respondents had completed higher education (95.8%) and most of the companies represented by experts had between 10 and 19 employees (54.2%). Most of the respondents had work experience in the construction field for 10 years or more (83.3%).

3.2 Ranking of the supply chain sustainability indicators

All interviews for this survey occurred between April 2022 and August 2022, and the main objective of the interviews was to determine the individual views of the respondents, taking into account their previous experience in the field of construction SC management.

The list of 38 SC sustainability indicators was divided into 7 sustainability groups: legal, physical, political, technological, economic, ecological, and social (Cataldo et al., 2021, 2022). The descriptions of each SCSI can be found in Tab. 3.

The experts were asked to rank the groups of sustainability and supply chain sustainability indicators in each group according to their importance. The questionnaire of the survey was given to respondents in paper format or sent by e-mail to 24 academics and top/middle managers in construction companies. A total of 78 questionnaires were submitted, of which 24 questionnaires were returned completed.

At first, the experts ranked the seven groups of indicators for supply chain sustainability using a 7-point scale. The scale ranged from 1 to 7, where 1 represented “extremely important” and 7 “not important at all.” The rankings of the sustainability indicator groups are shown in Tab. 4.

The rank sum weight method was selected because it is easy to apply in practice. The calculation of the sustainability group’s weights is carried out using Equations (1–7). The weight values and accuracy are determined by the assessment method, where the most significant i^{th} group of indicators receives the highest weight ω_i. To ensure proper allocation of weight to sustainability groups, the total weight assigned to sustainability groups must add up to one:

$$\sum_{i=1}^{n} \omega_i = 1 \tag{9}$$

where: n – number of groups of indicators.

Tab. 3: Supply chain sustainability indicators and their descriptions – Part 1

Groups of sustainability	Code	Indicators	Description, criteria and impact measurement
Ecological indicators	SI_1	Environmental impact	Changes brought about by human activity in the constructed or natural environment that may negatively impact the ecosystem's occupants in the company/Total changes to the environment by the project; *min*
	SI_2	Cost-saving initiatives due to sustainable practices	Improvement profitability implementing sustainable ideas/Total company's profitability; *max*
	SI_3	Load on nature	Load on nature in the company/Aimed load on nature; *min*
	SI_4	Sustainable labor practices	Amount of sustainable labor practices/Total amount of labor practices; *max*
Social indicators	SI_5	Project team satisfaction	Percentage of the satisfied project team members/Total amount of project team members; *max*
	SI_6	Targeted incentives and compensations	Paid bonuses to the employees/Promised bonuses; *max*
	SI_7	Education of employees and employers	Number of training hours/Total number of employees; *max*
	SI_8	Employee rights	Actual percentage of legal rights related to the working relationship between employers and employees in the company/Percentage of legal rights in the country; *max*
	SI_9	Public relationship	Actual recognition and acceptance of company's actions or behavior by others in a social setting/Aimed recognition and acceptance of company's actions; *max*
Legal indicators	SI_{10}	Environmental management	Reducing usage of water, electricity, gas/ Total usage of resources; *min*
	SI_{11}	Equitable risk management mechanism	Number of injuries/Total number of employees; *min*
	SI_{12}	Efficiency and cost	Efficiency of the materials/Total cost of materials; *max*
	SI_{13}	Best practice strategy	Actual use of best practices in the company/Aimed usage of best practice strategies; *max*
	SI_{14}	Fulfillment of contractor's responsibilities	Successfully completed projects/ All company's projects; *max*
	SI_{15}	Reports and documentation	The number of fully filled and documented activities/All activities; *max*

Tab. 3: Supply chain sustainability indicators and their descriptions – Part 2

Groups of sustainability	Code	Indicators	Description, criteria and impact measurement
Physical indicators	SI_{16}	Sustainable project implementation	Implementation of sustainable practices in the project/Total amount of practices; *max*
	SI_{17}	Sustainable use of resources	The use of sustainable resources/ All resources used by the company; *max*
	SI_{18}	Work execution and final results	Efficient final results/All work practices; *max*
	SI_{19}	Cooperation and development of mutual trust	Trust factor and happiness level within the employee/Total amount of workers; *max*
	SI_{20}	Employee accountability	Achievement of employee responsibilities/ Total amount of workers; *max*
	SI_{21}	Stakeholder engagement	Number of accredited stakeholders in the project/Total amount of workers in the project; *max*
Political indicators	SI_{22}	National and economic stability	Political and economic stability level of a country/An ideal level of stability; *max*
	SI_{23}	Rigorous selection process of suppliers	The amount of selection processes/ The total amount of suppliers working in the company; *max*
	SI_{24}	Company's ability to perform internationally	The number of projects and development internationally/Company's aimed level of internationality; *max*
	SI_{25}	Company's involvement in to the politics	Number of accredited professionals in politics/Total number of employees; *max*
	SI_{26}	Fulfilment in response time frame and timely payment	Actual date of payment/Planned date of payment; *max*
	SI_{27}	Transparency and holistic approach	Level of transparency of a company/Aimed level of transparency; *max*
Technological indicators	SI_{28}	Innovation and improvements	Number of innovations used/Total number of projects; *max*
	SI_{29}	Fulfilment of project team and customer's satisfaction	Percentage of satisfaction/The number of customers and employees; *max*
	SI_{30}	Use of sustainable materials	Number of sustainable materials/Total number of used materials; *max*
	SI_{31}	Implementation of new technologies	Implementation of new technologies/Number of available new technologies; *max*
	SI_{32}	Quality and productivity level	An actual productivity level/Planned productivity level; *max*
	SI_{33}	Application of systems	Usage of new systems in the operations/ Number of operations; *max*

Tab. 3: Supply chain sustainability indicators and their descriptions – Part 3

Groups of sustainability	Code	Indicators	Description, criteria and impact measurement
Economic indicators	SI_{34}	Profit performance	Profit per month/Planned profit per month; *max*
	SI_{35}	Resources and their successful management	Usage of resources/Planned usage of resources; *min*
	SI_{36}	Money planning	Direct costs per month/All planned costs per month; *min*
	SI_{37}	Charity and social activities	The involvement in social activities/Country's average for companies' involvement; *max*
	SI_{38}	Competition between companies and fair pricing	Company's prices/The country's average prices on the project; *min*

Note: *max* if a higher value of the supply chain sustainability indicator indicates a positive impact on sustainability (larger-the-better); *min* if a lower value of the supply chain sustainability indicator indicates a positive impact on sustainability (smaller-the-better)

Source: own

Among the 7 sustainability indicators groups that affect the management of the construction supply chain, economic indicators were found to be the most important group with a weight of 0.2188, while technological factors are the second most important with a weight of 0.2128, as shown in Tab. 4. Expert opinion suggests that economic and technological indicators play a crucial role in shaping the overall sustainability within the construction supply chain. Ecological considerations cannot be discounted when achieving a sustainable construction company, despite their slightly lower assigned weight (0.1711). To test the agreement among participants on sustainability indicators, a Kendall concordance test was conducted. Strong agreement in the ranking of the sustainability indicators groups was confirmed by Kendall's coefficient of concordance, $W = 0.6305$ ($\chi^2 = 90.786 > \chi^2_{\alpha,\upsilon} = 16.812$, $\alpha = 0.01$) ($0.5 \geq W > 0.7$ as defined by Hatefi, 2023).

Second, the experts ranked the indicators of the sustainability of construction companies according to their importance, from the most significant to the least significant. The scale used to rank these indicators ranged depending on the indicator number within the group. For example, from 1 to 6 for technological indicators, where 1 indicated "extremely important," and 6 indicated "not important at all," and from 1 to 5 for economic indicators, where 1 indicated "extremely important" and 5 indicated "not important at all," etc. The rankings of these sustainability indicators are shown in Tab. 4.

The calculation of the indicators' weights is carried out using Equations (1–8). The selected method acknowledges the variability in the number of indicators across sustainability groups, wherein the weight of each indicator is calculated relative to its respective group. The chosen assessment method determines the weight values and accuracy: the most significant i^{th} indicator will be given the highest individual weight w_i^{ind}. The total of the individual weights equal to the number of group indicators:

$$\sum_{i=1}^{x} w_i^{ind} = x \tag{10}$$

For example, the sum of individual weights of indicators of a group of economic indicators is 1.4305 + 1.3055 + 1.1250 + 0.4585 + 0.6805 = 5 (Tab. 4).

The global weight of each indicator was calculated by multiplying the individual weight and the weight of the group. The resulting values were normalized, so that the sum of all global weights, w_i^{gl} is equal to 1. Based on this, the rank of each evaluated indicator was determined.

Tab. 4: Supply chain sustainability indicators ranking with local, individual, and global weights – Part 1

Group of sustainability	Weight of group	Code	Indicator	Local weight (w_i)	Individual weight (w_i^{ind})	Global weight	Global normalized weight (w_i^{gl})	Rank
Ecological indicators (Eco)	0.1711	SI_1	Environmental impact	0.2833	1.1332	0.1939	0.0360	9
		SI_2	Cost-saving initiatives due to sustainable practices	0.3625	1.4500	0.2481	0.0461	6
		SI_3	Load on nature	0.1792	0.7168	0.1226	0.0228	19
		SI_4	Sustainable labor practices	0.1750	0.7000	0.1198	0.0223	20
Social indicators (Soc)	0.0595	SI_5	Project team satisfaction	0.1694	0.8470	0.0504	0.0094	35
		SI_6	Targeted incentives and compensations	0.2417	1.2085	0.0719	0.0134	30
		SI_7	Education of employees and employers	0.2889	1.4445	0.0859	0.0160	26
		SI_8	Employee rights	0.2194	1.0970	0.0653	0.0121	34
		SI_9	Public relationship	0.0806	0.4030	0.0240	0.0045	38
Legal indicators (Leg)	0.0818	SI_{10}	Environmental management	0.2163	1.2978	0.1062	0.0197	23
		SI_{11}	Equitable risk management mechanism	0.0893	0.5358	0.0438	0.0081	36
		SI_{12}	Efficiency and cost	0.2579	1.5474	0.1266	0.0235	18
		SI_{13}	Best practice strategy	0.2123	1.2738	0.1042	0.0194	24
		SI_{14}	Fulfillment of contractor's responsibilities	0.1567	0.9402	0.0769	0.0143	29
		SI_{15}	Reports and documentation	0.0675	0.4050	0.0331	0.0062	37
Physical indicators (Phys)	0.1250	SI_{16}	Sustainable project implementation	0.2321	1.3926	0.1741	0.0324	13
		SI_{17}	Sustainable use of resources	0.2381	1.4286	0.1786	0.0332	11
		SI_{18}	Work execution and final results	0.2341	1.4046	0.1756	0.0326	12
		SI_{19}	Cooperation and development of mutual trust	0.0893	0.5358	0.0670	0.0124	33
		SI_{20}	Employee accountability	0.1131	0.6786	0.0848	0.0158	27
		SI_{21}	Stakeholder engagement	0.0933	0.5598	0.0700	0.0130	31
Political indicators (Pol)	0.1310	SI_{22}	National and economic stability	0.2639	1.5832	0.2074	0.0386	8
		SI_{23}	Rigorous selection process of suppliers	0.2302	1.3811	0.1809	0.0336	10
		SI_{24}	Company's ability to perform internationally	0.0873	0.5237	0.0686	0.0128	32
		SI_{25}	Company's involvement in to the politics	0.1488	0.8927	0.1169	0.0217	21
		SI_{26}	Fulfilment on response time frame and timely payment	0.1687	1.0121	0.1326	0.0246	16
		SI_{27}	Transparency and holistic approach	0.1012	0.6071	0.0795	0.0148	28

Tab. 4: Supply chain sustainability indicators ranking with local, individual, and global weights – Part 2

Group of sustainability	Weight of group	Code	Indicator	Local weight (w_i)	Individual weight (w_i^{ind})	Global weight	Global normalized weight (w_i^{gl})	Rank
Technological indicators (Tech)	0.2128	SI_{28}	Innovation and improvements	0.2421	1.4526	0.3091	0.0575	2
		SI_{29}	Fulfilment of project team and customer's satisfaction	0.1329	0.7974	0.1697	0.0315	14
		SI_{30}	Use of sustainable materials	0.2103	1.2618	0.2685	0.0499	5
		SI_{31}	Implementation of new technologies	0.1012	0.6072	0.1292	0.0240	17
		SI_{32}	Quality and productivity level	0.2302	1.3812	0.2939	0.0546	3
		SI_{33}	Application of systems	0.0833	0.4998	0.1064	0.0198	22
Economic indicators (Econ)	0.2188	SI_{34}	Profit performance	0.2861	1.4305	0.3130	0.0582	1
		SI_{35}	Resources and their successful management	0.2611	1.3055	0.2856	0.0531	4
		SI_{36}	Money planning	0.2250	1.1250	0.2462	0.0458	7
		SI_{37}	Charity and social activities	0.0917	0.4585	0.1003	0.0186	25
		SI_{38}	Competition between companies and fair pricing	0.1361	0.6805	0.1489	0.0277	15

Source: own

The ranking of each sustainability indicator with local, individual, global weights, and global normalized weights is displayed in Tab. 4.

To assess agreement on the ranking the sustainability indicators within a group, a Kendall test of concordance was conducted. Kendall's W and χ^2 values for each group of sustainability indicators are presented in Tab. 5.

As shown in Tab. 5, a very strong consensus ($0.7 \geq W > 0.9$ as defined by Hatefi, 2023) emerged among experts, highlighting the importance of both legal and psychological factors. Furthermore, participants strongly agree ($0.5 \geq W > 0.7$) that diverse factors – economic, political, technological and social – are vital for sustainable construction practices. Additionally, the experts expressed a fair consensus ($0.3 \geq W > 0.5$) regarding the importance of ecological factors for enhancing the sustainability of construction companies.

The three most important indicators (profit performance ($w_{34}^{gl} = 0.0582$), innovation and improvements ($w_{28}^{gl} = 0.0575$), and quality and productivity level ($w_{32}^{gl} = 0.0546$)) emphasize

Tab. 5: The concordance and chi-square values of each group

Parameters	Group of sustainability						
	Eco	Soc	Leg	Phys	Pol	Tech	Econ
W	0.4882	0.5674	0.7258	0.7103	0.6147	0.6046	0.6208
χ^2	35.1500	54.4670	87.0950	85.2380	73.7620	72.5480	59.6000
df	3	4	5	5	5	5	4
$\chi^2_{\alpha,v}$	11.3450	13.2770	15.0860	15.0860	15.0860	15.0860	13.2770

Note: α = 0.01; df – degree of freedom; for the explanation of the abbreviations see Tab. 4.

Source: own

the crucial role of financial and operational performance in achieving sustainability for construction companies. This suggests that experts view sustainability as strategic and financially viable in the long term, not just an environmental or social responsibility. Although financial and operational performance is prioritized, the inclusion of indicators such as resource management ($w_{35}^{gl} = 0.0531$), the use of sustainable materials ($w_{30}^{gl} = 0.0499$), and cost-saving initiatives due to sustainable practices ($w_{2}^{gl} = 0.0461$) demonstrates an awareness of the need to balance economic goals with environmental considerations.

3.3 Normalization of sustainable chain sustainability indicators

Normalization is the following stage, which is required because indications are typically expressed in different units. The proportion of annual variances over consecutive years, distance to a reference, and minimum-maximum are examples of possible normalizing techniques (Oliveira et al., 2019; Zhou et al., 2012). The normalized value is computed as the ratio of the indicator to an external benchmark (or target value) when a distance is applied to a reference method. Legal requirements in the area, industry norms, and standards, or any other pertinent documentation might be used to define the external benchmark.

To effectively evaluate sustainability indicators, a reference point is crucial. This paper proposes using goal values for each indicator. Sustainability indicators fall into two categories: those where higher values benefit sustainability (*max*) and those where lower values benefit sustainability (*min*). The normalization equation varies according to the indicator (*max* or *min*; Tab. 3). The indicators SI_i are normalized by equations:

$$SI_{Ni} = \frac{SI_i^{max}}{SI_i^{targ}} \tag{11}$$

$$SI_{Ni} = \frac{SI_i^{targ}}{SI_i^{min}} \tag{12}$$

where: SI_i^{max} – the value of i^{th} supply chain sustainability indicator which higher value indicates a positive impact on sustainability (larger-the-better); SI_i^{min} – the value of i^{th} supply chain sustainability indicator which lower value indicates a positive impact on sustainability (smaller-the-better); SI_i^{targ} – the target value of i^{th} sustainability indicator; $0 \le SI_{Ni} \le 1$.

The indicators do not have dimensions after normalization and range from 0 to 1, where 0 represents the worst and 1 represents the greatest. Each construction company should establish goals for each metric; for example, the use of sustainable materials (Tab. 3) should represent at least 80% of the total materials related to the company's operations. Thus, SI_i^{targ} equals 80%. Assume that SI_{21} 50% is the company's usage. Then the indicator's normalized value SI_{N21} would be equal to 0.625.

3.4 Aggregation of indicators and creating the composite sustainability index for SCM in construction companies

The final stage is called aggregation. At this point, a sustainability index for construction companies (an overall measure) is created. The summing-up of the weighted and normalized individual indicators is the most popular method of aggregation.

A construction company's composite sustainability index for SCM is established by:

$$CISSC = \sum_{i=1}^{n} w_i^{gl} SI_{Ni} \tag{13}$$

where: *CISSC* – a composite index of sustainable supply chain; w_i^{gl} – the normalized global weight of sustainability indicator *i*; SI_{Ni} – the normalized value of sustainability indicator *i*; *n* – number of indicators.

$$0 \le CISSC \le 1$$

$$\begin{aligned} CISSC = {} & 0.0360SI_{N1} + 0.0461SI_{N2} + \\ & + 0.0228SI_{N3} + 0.0223SI_{N4} + 0.0094SI_{N5} + \\ & + 0.0134SI_{N6} + 0.0160SI_{N7} + 0.0121SI_{N8} + \\ & + 0.0045SI_{N9} + 0.0197SI_{N10} + 0.0081SI_{N11} + \\ & + 0.0235SI_{N12} + 0.0194SI_{N13} + 0.0143SI_{N14} + \\ & + 0.0062SI_{N15} + 0.0324SI_{N16} + 0.0332SI_{N17} + \\ & + 0.0326SI_{N18} + 0.0124SI_{N19} + 0.0158SI_{N20} + \\ & + 0.0130SI_{N21} + 0.0386SI_{N22} + 0.0336SI_{N23} + \\ & + 0.0128SI_{N24} + 0.0217SI_{N25} + 0.0246SI_{N26} + \\ & + 0.0148SI_{N27} + 0.0575SI_{N28} + 0.0315SI_{N29} + \\ & + 0.0499SI_{N30} + 0.0240SI_{N31} + 0.0546SI_{N32} + \\ & + 0.0198SI_{N33} + 0.0582SI_{N34} + 0.0531SI_{N35} + \\ & + 0.0458SI_{N36} + 0.0186SI_{N37} + 0.0277SI_{N38} \end{aligned}$$

The developed CISSC provides a global view of sustainable supply chain management in construction companies, allowing the supply chain indicators regarding their goals. This methodology proposes a straightforward

procedure to consolidate existing supply chain indicators related to the same process into a single analysis without requiring significant resources.

The developed CISSC enables construction companies to comprehensively assess supply chain sustainability practices. This methodology allows construction companies to efficiently compare their sustainability goals with minimal effort. This methodology simplifies the analysis of various supply chain indicators that contribute to the same process and provides actionable insights.

Sustainability assessments are crucial for construction companies, not only to fulfil their environmental commitments, but also for the potential of long-term business success. It is important to note that evaluating the sustainability of the supply chain can be a complex process and may require consultation with sustainability experts. Continuous monitoring and improvement of supply chain sustainability indicators is crucial for the organization to adapt to changing conditions and enhance its sustainability performance.

Conclusions

Construction companies are now aware of their moral and social obligations, particularly with regard to environmental protection. Companies have been making efforts to encourage sustainable practices. One of the most important measures construction companies must take to promote sustainability in their overall work culture is the list of key sustainability indicators in SSCM. To ensure minimal environmental effect and gain a competitive edge in the market, managers themselves are beginning to understand the importance of sustainable behavior.

When determining the indicators that have the most important influence on the management of sustainable construction supply chains, this influence was found to depend not only on the importance of the indicator in its group, but also on the importance of the group itself and the number of indicators in that group. This research identified 38 sustainability indicators, including seven critical groups specifically relevant to construction industry practitioners. Furthermore, the examination of the relevance of the indicators showed that the economic criteria are the most important for construction companies, followed by the environmental and social indicators. More research needs to be done to ensure that the list of criteria and factors that determine how important they are considered is accurate. When the needs and goals of all stakeholders are met to the highest possible degree, sustainable development can be achieved. As a result, society, sustainability experts, and architects will be involved in future research because their perspectives may differ due to their diverse backgrounds in the workplace or the representation of various interest groups.

During this scientific work, using the most important sustainability indicators in construction companies, an integrated methodology for the development of a composite index to measure sustainability of a supply chain management in construction companies is presented. An index helps construction companies evaluate their sustainability according to their aimed plans, which can be used not only in Lithuania, but also in the construction industry of the EU and other foreign countries.

The developed CISSC offers construction companies a global perspective on sustainable supply chain management. This enables them to effectively benchmark their supply chain indicators against sustainability targets. The methodology's streamlined approach consolidates related supply chain indicators for simplified analysis, maximizing efficiency and minimizing resource requirements. It is crucial to acknowledge that the importance of the sustainability indicator can fluctuate depending on the specific project context and established priorities. Nevertheless, this analysis provides valuable insight into the prevailing priorities within the realm of construction supply chain sustainability.

Further research should explore the dynamics that influence the weighting of these indicators, particularly investigating how they vary between diverse countries, project types, and company sizes. By incorporating such findings into future studies, a more context-specific perspective on sustainable construction supply chain management can be achieved. Future research should also consider the development and integration of more indicators to support the transition of construction supply chains to higher levels of circularity.

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Assessment of the development potential of the tourism industry in Czechia on the basis of smart specialization

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Abstract: *The tourism industry is constantly evolving and requires the introduction of the latest technologies and development tools, such as smart specialization, which contributes to the economic development of countries, the welfare of the population, and an increase in foreign exchange earnings. The aim of the article is to assess the potential for the development of the Czech tourism industry on the basis of smart specialization using the integral indicator of smart specialization potential. The research methodology includes mathematical and economic, abstract and logical statistical, and expert analyses. The introductory part defines the content and components of smart specialization. At the next stage, the level of innovation, economic and investment, social and scientific components of Prague and other regions of Czechia was assessed, which determined the potential for the development of the Czech tourism industry on the basis of smart specialization using the integral indicator of smart specialization potential. The research results suggest ways to introduce smart specialization into the Czech tourism industry, including investment support for the implementation of smart strategies of the Czech regions; improvement of the regulatory framework for creating new business models for the development of tourism enterprises; ensuring the development of transport infrastructure, power grids, and digital networks; and improving social support for citizens; creating an environment in which it is possible to create and implement. The originality of the study is an approach to assessing the potential for the development of the Czech tourism industry on the basis of smart specialization using the proposed integral indicator of smart specialization potential. The practical significance is due to the possibility of using the integral indicator of smart specialization potential as a tool for allocating investment resources to ensure the development of the tourism industry of Czechia and its regions, which will be useful for the Czech government agencies to increase the potential of the country's tourism industry.*

Keywords: *Smart specialization, tourism, innovation, assessment, potential.*

JEL Classification: *O14, Z32.*

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Introduction

The aim of the article is to assess the potential for the development of the Czech tourism industry on the basis of smart specialization using the integral indicator of smart specialization potential.

The current model of sustainable development of the Czech economy in the tourism sector as a whole and in its regional components is based on the continuous transformation of modern scientific and technical progress into advanced technologies, quality goods, and services.

The specified topic is the subject of own research, which is the basis for continuing scientific research in a certain direction (But, 2023; But et al., 2023; But, 2024a,b). It is the basis for further research on the development of the Czech tourism industry by assessing the potential for the development of the Czech tourism industry on the basis of smart specialization. To determine the priority areas of regional development and the introduction of smart technologies, the authors propose to use an integral indicator of the smart specialization potential. This indicator helps to identify areas of innovative potential for the development of the Czech tourism industry based on the fact that each region can find its own competitive advantages in the use of smart technologies. This study should determine which tourist flows allow the effective use of regional resources and provide better service for tourists.

This necessitates the development and implementation of effective measures at both the state and regional levels to concentrate resources and efforts on the priority areas of scientific, technical, social, and economic development of the tourism industry within a market economy, improve living standards, and ensure compliance with social standards guaranteed by the state for every citizen.

One such measure is the inclusion of smart specialization in the strategic planning framework for regional development, which is already provided for in the relevant legal framework. In this context, it is particularly important to define strategic guidelines for the long-term development of the Czech tourism sector.

The smart specialization approach determines the innovative potential of a region and contributes to the transformation of its economy (Berezina, 2018). This approach identifies regional development actors that operate within the framework of regional strategies with specific strategic goals and objectives for economic development. Fig. 1 shows what a smart specialization is.

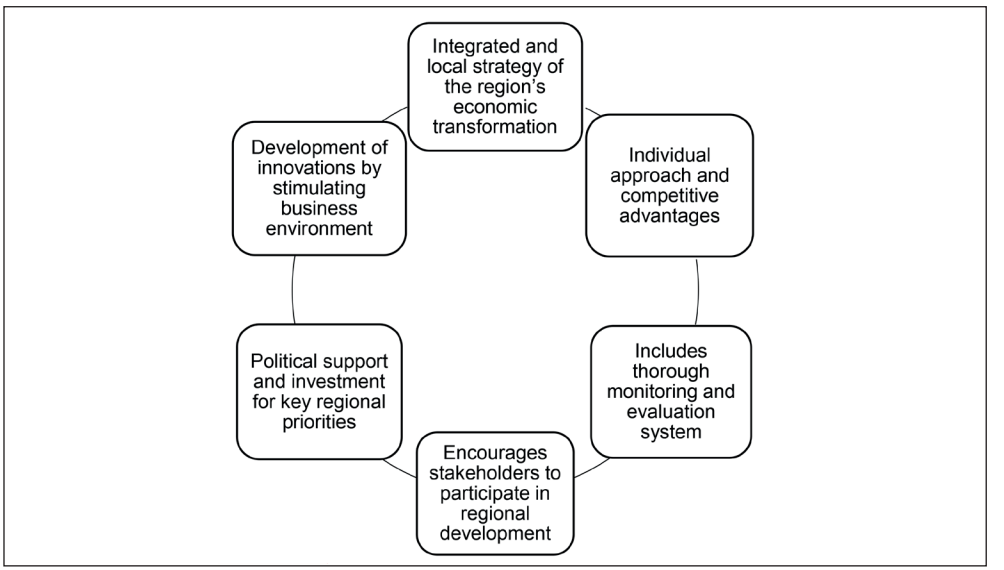

Fig. 1: Smart specialization

Source: own

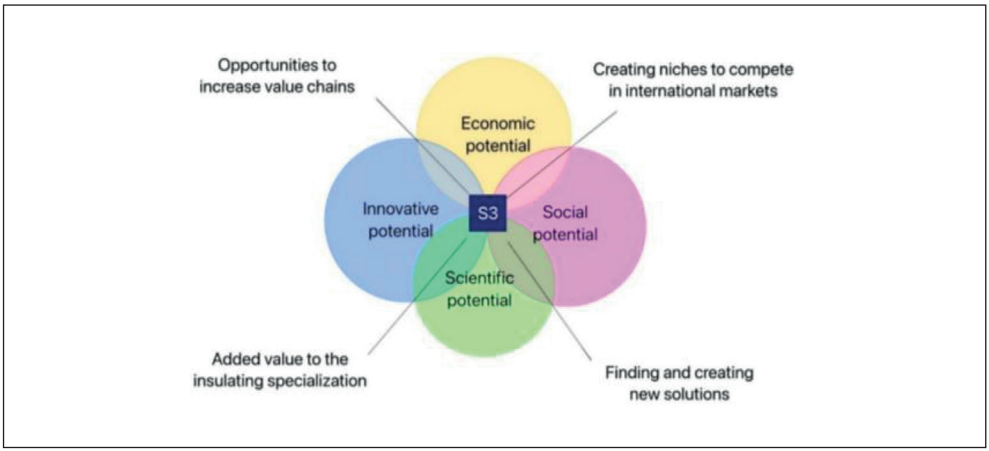

Fig. 2: RIS3 value – the components of the smart specialization

Source: Ministry of Industry and Trade (2021)

The components of the smart specialization concept are shown in Fig. 2. Components of smart specialization maximize our strengths and unique combination of capabilities, combining our economic past with our research and innovation capabilities.

Innovation potential includes the availability of an innovatively open business environment and a powerful educational sphere that will provide highly qualified personnel in the labour market and increase the competitiveness of scientific personnel. Scientific potential is made up of the availability of a competitive sectoral scientific sphere through the use of economic and scientific potential of young foreigners, the level of human resources, their qualifications, and scientific and technical capabilities. Social potential implies satisfying the level of quality of life, its improvement, a high level of medicine, access to free education, and birth rate. Investment potential consists of the availability of sufficient investment and financing in the region's educational and scientific spheres. The economic potential involves the total amount of tourism services provided, the number of tourism enterprises, the number of full-time employees at tourism enterprises, and the average monthly salary of tourism employees. Therefore, the integral indicator of the smart specialization potential for innovative development of the Czech tourism industry will be determined by assessing the scientific, social, investment, and economic potential of Czechia.

In particular, the study of the development of the tourism industry is carried out either by individual regions or a specific method. For example, an analysis of the social and economic potential of the tourism industry in some regions was conducted by Burda et al. (2023), where qualitative research methods were used, using questionnaires and structured interviews. The social, economic, and innovative potentials of the tourism industry in the Czech region were studied by But (2024) using such methods as Porter's model of the five forces of competition, ABC analysis, and strategic mapping. The indicators of the social and economic potential of the tourism industry are studied by the method of cluster analysis in Gudz et al. (2023).

All these and other methods are focused on the study of satisfaction with the population's quality of life and do not simultaneously consider the components of innovative scientific, social, investment, and economic potentials. Therefore, we will assess the potential for the development of the Czech tourism industry based on these components based on smart specialization by determining the integral indicator of the smart specialization potential for the innovative development of the Czech tourism industry, which determines the relevance of the chosen topic.

1. Theoretical background

The concepts of "smart" and "smart specialization" defined above are general concepts that almost everyone has encountered. Taking into account the introduction of intelligent components into the European model of regional development, the realization of scientific, social, investment, and economic potentials is studied through integrated approaches to the use of all components in urban community development strategies. Therefore, the collection of scientific literature sources was focused on researching scientific approaches to smart specialization, smart cities, and tourism development.

Šulyová and Kubina (2022) studied the comparison of the currently identified elements that influence the development of the sustainable development concept of a smart city in Slovakia by taking into account the best practices of cities around the world. This approach reflects the social, environmental, technological, and governance components of cities, which are useful for the city authorities.

The problematic areas of implementing the smart city concept for Bratislava on the example of Vienna, which is considered one of the best smart cities in Europe, were studied by Adamuscin et al. (2016). The research points to the impact of transformational changes in the economy and technological processes arising from integration and globalization. This approach has revealed the interdependence of smart specialization and the quality of urban life. The imperfection of the economy, social environment, urban culture, and human and social capital define the problems of implementing the smart strategy in the European cities.

The concept of "smart cities" in relation to social innovations was studied by Husar and Ondrejicka (2019). This approach focuses on creating an environment for social innovation based on smart specialization by using information and communication technology (ICT) tools.

Fernández and Peek (2020) studied urban initiatives to understand the extent to which smart cities can be a response to climate change based on innovative efforts. The analysis of this approach demonstrates the interaction between technology and nature and points to the importance of adapting smart infrastructure and its impact on the climate, which puts the environment at the center of its development.

Saketh and Puppala (2023) explored the mission of "smart city," aimed at modernizing the existing cities by improving core infrastructure through the introduction of smart objects and cybersecurity, which are useful for effective management in tourism. This approach will improve the information and innovation resources for implementing smart specialization through effect variables.

Researchers Jurigová and Tučková (2018) evaluated the economic indicators used by hotel companies to manage their economic performance on the example of the hotel business in the Zlín region of Czechia. This approach introduced a system of indicators of economic sustainability of the hotel business and indicated what economic components make up the economic potential of the tourism industry.

Farmaki et al. (2021) used a multi-criteria decision-making method for medium-sized European tourist cities using 10 criteria. The researchers used 11 measures of urban mobility to assess smart specialization in tourism. This approach points to using smart specialization models (personalized plans and smart applications) in shaping future sustainable mobility policies in urban tourist destinations, which are a priority in improving the quality of life and well-being of the citizens.

Panyadee et al. (2023) explored smart wellness cities with the help of the latest achievements of this type of tourism, analyzing the development of these cities. This approach points to developing tourism through the latest technologies under the influence of innovation potential, strategic planning, management, marketing, and competitiveness of all stakeholders.

Meyer et al. (2022) studied the tourism of the cultural and creative industries of the South Baltic Sea, which are part of the economic ecosystem and make a powerful contribution to the revival of sustainable development in this region. This approach to studying the resilience and restoration of sustainable tourism development in the post-pandemic era on the basis of smart specialization has pointed to the lack of interconnection between the potential of the creative and cultural industries and their contribution to the co-creation of a smart specialization strategy.

Brumen et al. (2016) studied the impact of ICT (information and communication technologies) on tourism by correlating statistical indicators and determined that only 30% of the web pages of tourism enterprises are in the internet

database. This approach has shown that the development of regional tourism indicators is driven by a smart specialization strategy.

Romao (2020) studied the impact of innovative technologies on regional tourism. The scientist found out the high tourism potential of regions affected by smart specialization strategies. The study has shown the positive impact of the smart specialization strategy on the high potential of the tourism sector due to the interaction of unrelated destination sectors.

Chamusca (2023) investigates smart specialization in tourism through the use of smart strategies, which resulted in the importance of creating networks and partnerships in Europe for economic, social, and environmental development. This approach emphasizes the possibility of developing tourism by increasing investment and innovation potential.

Ndou et al. (2023) investigated a methodological framework aimed at supporting the creation of a smart tourism destination using the example of the southeastern Adriatic-Ionian region as part of the European macro-region; along with the objectives of the EU's Smart Specialization Strategy, several initiatives aimed at innovating the tourism offer in this region have been supported. This approach also points to introducing innovative potential into the tourism industry.

The above approaches and methods of using smart strategies determine the positive impact of smart specialization on the development of European countries and the development of the tourism industry. However, it is necessary to find out whether the smart specialization strategy in Czechia is effective, how it affects the potential for tourism development in the country's regions, and whether it improves the welfare of the population. To do this, we will diagnose the social, economic, scientific, and innovative potentials of the Czech tourism industry, which are components of smart specialization, which will allow us to achieve the purpose of the study and determine the relevance of the chosen topic.

2. Research methodology

In the course of the study, the following methods of economic research were used: a mathematical and economic one to develop a methodology for calculating the integral indicator (when assessing the smart specialization potential of the Czech tourism industry); an abstract and logical one (for theoretical generalizations and formulation of conclusions); a statistical one (for diagnosing the social, economic, scientific, and innovative potentials of the Czech tourism industry, which are components of smart specialization); and an expert method of collecting primary information and processing the collected secondary information.

The research was facilitated by the documentation of the Czech and international authorities: Ministry of Industry and Trade Czech Republic (National research and innovation strategy for smart specialisation of the Czech Republic 2021–2027 – National RIS3 strategy); Czech Statistical Office; CzechTourism (Marketing and destination management plan 2023; Shaping the image of the Czech Republic – CCCR annual report 2022; Concept of unified foreign presentation of the Czech Republic); Research, Development and Innovation Council Czech Republic (Innovation strategy of the Czech Republic 2019–2030. The country for the future); UN Tourism (World tourism barometr 2023; Global tourism code of ethics; Tourism in the 2030 agenda); European Travel Commission (Climate action plan 2050); Economic Commission for Europe (Applying principles of circular economy to sustainable tourism); CAREC (Tourism development strategy CAREC 2030).

The study to assess the potential for the development of the Czech tourism industry on the basis of smart specialization was conducted based on statistical data from the city of Prague and 13 regions of the country and in the following stages, which are shown in Fig. 3.

The levels (P_l) of innovative, social, economic, and investment potentials were assessed on the basis of the data from the main city of Czechia, Prague, using the following methodology:

$$P_l = \sum P_i * W_i \quad (1)$$

where: P_i – an expert assessment of using innovative, social, economic, and investment potentials (points); W_i – the weighing coefficient of the elements of innovative, social, economic and investment potentials.

The integral indicator of smart specialization potential is determined by the following methodology:

$$P_{SM} = \sqrt[4]{P_{in} * P_n * P_s * P_{sc}} \quad (2)$$

where: P_{SM} – the potential of smart specialisation; P_{in} – innovative potential, P_s – social;

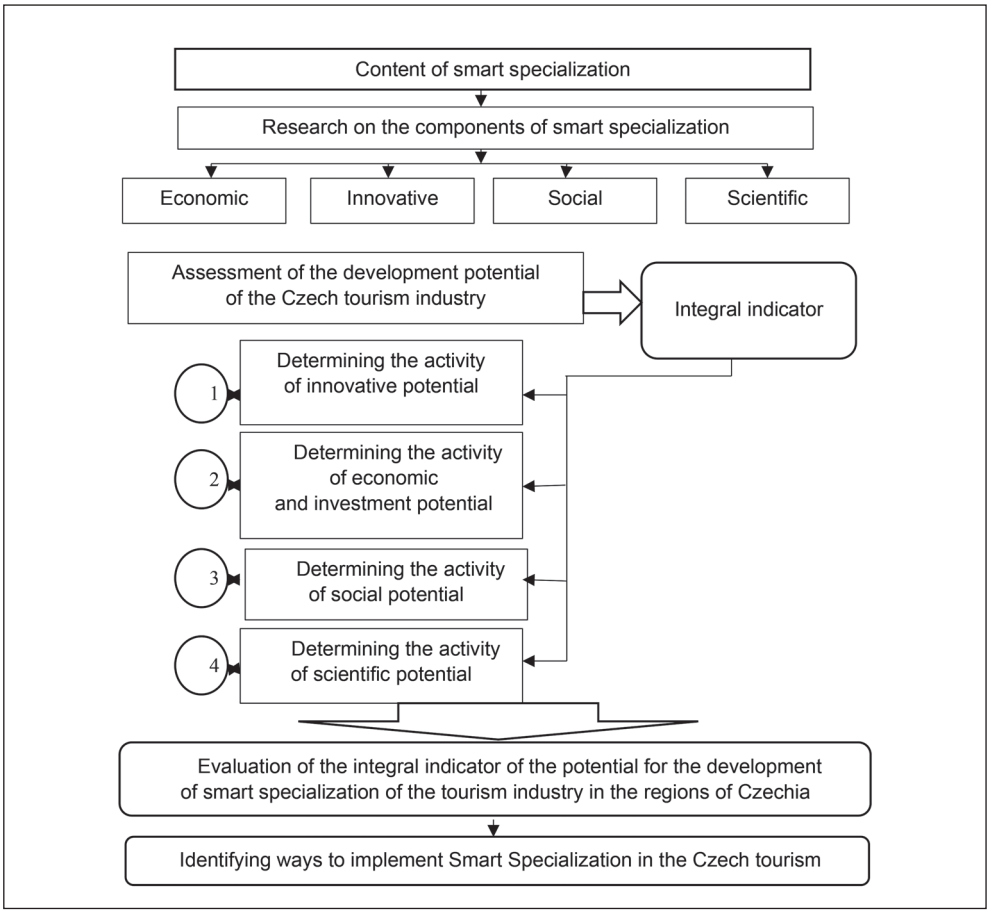

Fig. 3: **Stages of the study to assess the potential for the development of the Czech tourism industry on the basis of smart specialization**

Source: own

P_n – economic and investment; P_{sc} – scientific.

The data for the study of innovation, social, economic and investment potentials were selected for the period 2021–2022 based on the latest available data from the Czech and national economies (BusinessINFO.cz, 2023; CSO, 2023; UNWTO, 2023).

3. Results and discussion

3.1 Analysis of the tourism potential of the Czech regions

The European Union has 120 smart strategies at the regional and national levels (Fig. 2). This approach is already being applied in 12 countries.

Czechia has developed a National RIS3 strategy for 2021–2027. Also, some Czech regions have developed a separate RIS3 strategy for 2021–2027. The long-term strategic vision of the national RIS3 of a sustainable economy based on knowledge and innovation formulates the main direction of Czechia's development (Ministry of Industry and Trade, 2021). It emphasizes the knowledge economy and the transformation of the economy in such a way as to increase competitiveness based on innovation rather than low costs. The strategy identifies areas of applied research in which it makes sense to invest from the state and EU funds since 2021 over the next six years.

It should be noted that the unification of the European Union is taking place, among other things, due to the existence and implementation of the smart specialization strategy, which is a fundamental condition for the implementation of political measures. The EU sets seven criteria to fulfil this basic condition.

Therefore, Czechia has the directions for the tourism industry development specified in the smart strategy for regional development. The top five leaders in terms of tourism potential by area were the city of Prague, Liberec, Hradec Králové, Moravian-Silesian, and Zlín regions. The top five leaders in terms of point potential were the regions of Central Bohemia (including Prague), South Bohemia, South Moravia, Pilsen, Moravian-Silesian, and Zlín (CSO, 2023).

The study found that the city of Prague, South Moravian, Hradec Králové, South Bohemia, and Central Bohemia regions have particularly favourable conditions for the tourism industry development, while the other regions have to determine the specific activities that will form the basis of their region's smart specialization.

3.2 Assessment of the development potential of the Czech tourism industry

A methodical approach to assessing the prerequisites for the implementation of smart specialization in the Czech regions is proposed, which is based on an integral indicator of smart specialization potential that includes the diagnosis of four potentials: innovative, social, economic and investment, and scientific, based on the method of expert assessments, namely the Delphi method. Experts are proposed to evaluate the researched object using this method. It consists of a survey in several iterations. In particular, each expert quantitatively evaluates the object. Next, the average value of the grades and their deviation from it are calculated. For experts who evaluated the object with the maximum deviation from the average value, it is recommended to justify their decisions. They are brought to all other experts and a second iteration of the survey is developed. A characteristic feature of the method is the reduction of the dispersion of experts' estimates from iteration to iteration and the increase of their consistency. Iterations are stopped if there is sufficient agreement between the experts' evaluations (link). The components and parameters of elements of the potential of smart specialization were determined by experts. Heads of tourism departments of ten regional administrations were appointed as experts.

The integral indicator of smart specialization potential is determined by Equation (3):

$$P_{SM} = \sqrt[4]{P_{in} * P_n * P_s * P_{sc}} \tag{3}$$

where: P_{SM} – the potential of smart specialisation; P_{in} – innovative potential; P_s – social; P_n – economic and investment; P_{sc} – scientific.

It is advisable to assess the level of the integral indicator of the potential of smart specialization on the following scale: 0 to 5.5 – low level, 5.5 to 8.0 – medium level, and from 8.1 to 12.0 – high level.

It is the integral indicator of smart specialization potential that makes it possible to assess the prospects for the development of the Czech tourism industry. Tab. 1 shows the procedure for assessing the innovative potential of the development of the tourism industry of Prague.

$$P_{in} = \sum P_i * W_i \tag{4}$$

where: P_{in} – innovative potential of the tourism industry in the city of Prague; i – the number of the element of the innovative potential of the tourism industry in Prague; P_i – the expert assessment of using the element of innovation potential of the tourism industry in Prague (points); W_i – the weighting coefficient of the element of the innovation potential of the tourism industry in Prague.

$$P_{in} = \sum P_i * W_i = 1.28 + 1.98 + \\ + 1.7 + 1.92 + 1.76 + 1.19 = 9.83 \tag{5}$$

The level of innovation activity of tourism enterprises in Prague is assessed on the following scale: 0 to 5.5 – low level, 5.5 to 8.0 – medium level, and from 8.1 to 12.0 – high level. The analysis showed that the tourism industry in Prague has a high level of innovation activity (9.83).

The result of the calculated assessment indicates the successful implementation of information technologies and automation by tourism infrastructure departments (hotel and restaurant, transport, and entertainment). New technologies make it possible to organize high-quality leisure activities in a flexible and segmented manner, which is more competitive compared to traditional offers. Mass, standard,

Tab. 1: Expert assessment of the state of the elements of innovation potential of development of the tourism industry in Prague

Components	Parameters	Weight	Prague	
			Points (1–3)	Balanced assessment
1. Resource provision	1.1 The degree of using tourist infrastructure	0.16	3	1.28
	1.2 The level of progressiveness of the applied service delivery technologies		2	
	1.3 The degree of tourist services flexibility		3	
	Final score		8	
2. Human resources	2.1 Level of staff qualifications	0.18	3	1.98
	2.2 The degree of staff's readiness for changes in tourism enterprises		2	
	2.3 Development of the staff motivation system		3	
	2.4 The degree of staff's creative initiative		3	
	Final score		11	
3. Scientific and technical capabilities	3.1 The level of expenditures on scientific research in the field of tourism	0.17	2	1.70
	3.2 The number of new types of tourist services		3	
	3.3 The number of new technologies		3	
	3.4 A share of staff engaged in scientific research of the total staff number		2	
	Final score		10	
4. Marketing capabilities	4.1 Rationality of using distribution channels for tourism services	0.16	3	1.92
	4.2 Flexibility of pricing policy		3	
	4.3 The level of advertising		3	
	4.4 Efficiency of the system of providing tourist services		3	
	Final score		12	
5. Organizational capabilities	5.1 Degree of innovation orientation of organizational structures	0.16	2	1.76
	5.2 The level of compliance of organizational culture with the innovative development of tourism enterprises in the regions		3	
	5.3 The level of managers' competence		3	
	5.4 Development of the information support system		3	
	Final score		11	
6. Scientific capabilities	6.1 The number of applications for utility models in the field of tourism	0.17	2	1.19
	6.2 The number of patents for inventions		2	
	6.3 The number of doctors of sciences		1	
	6.4 The number of candidates of sciences		2	
	Final score		7	
Weighted average final score			**9.83**	

Source: own

and comprehensive tourism is being replaced by new types of tourism developed by request and based on demand. Today, the transformation of tourism services digitalization is facilitated by introducing the latest e-tourism, e-travel, and tourism information systems.

An assessment of the economic and investment potential of the development of the tourism industry in Prague is presented in Tab. 2.

Based on the results of assessing the constituent elements of the economic and investment potential of the tourism industry in Prague, we will determine the economic and investment opportunities of the tourism industry in Prague. It should be noted that the higher the level of using the constituent elements of the economic and investment potential of the tourism industry development in Prague, the more competitive advantages the tourism industry enterprises have for the implementation of effective economic and investment activities of the tourism industry in Prague.

The final stage of assessing the economic and investment potential of Prague involves

Tab. 2: Expert assessment of the state of the elements of economic and investment potential of development of the tourism industry in Prague – Part 1

Components	Parameters	Weight	Prague	
			Points (1–3)	Balanced assessment
1. Tourism enterprises	1.1 The number of tourism enterprises	0.09	3	1.08
	1.2 A share of unprofitable tourism enterprises		3	
	1.3 The number of tourism enterprises that implemented innovations (units)		3	
	1.4 A share of innovatively active tourism enterprises (% of the total number of surveyed tourism enterprises)		3	
	Final score		12	
2. Total volume of tourism services	2.1 Total volume of tourism services provided in actual prices (CZK million)	0.08	3	0.24
	Final score		3	
3. State of accommodation facilities	3.1 Availability of accommodation facilities	0.1	3	0.90
	3.2 A share of accommodation facilities in the total cost (%)		3	
	3.3 Degree of depreciation of accommodation facilities		3	
	Final score		9	
4. State of restaurant services	3.1 Availability of restaurant business establishments	0.09	3	0.81
	3.2 A share of restaurant business establishments in the total value (%)		3	
	3.3 Degree of depreciation of restaurant business establishments		3	
	Final score		9	
5. Operating profitability of tourism enterprises (%)	5.1 Operating profitability of tourism enterprises (%)	0.09	3	0.27
	Final score		3	

Tab. 2: Expert assessment of the state of the elements of economic and investment potential of development of the tourism industry in Prague – Part 2

Components	Parameters	Weight	Prague	
			Points (1–3)	Balanced assessment
6. Investments in the tourism industry in actual prices (CZK million)	6.1 Investments in the tourism industry in actual prices (CZK million)	0.09	3	0.27
	Final score		3	
7. State of labour market	7.1 The number of full-time employees of tourism enterprises (thousand people)	0.09	3	0.54
	7.2 Average monthly salary of employees in the tourism sector (CZK)		3	
	Final score		6	
8. Level of productive forces development and state of investment market	8.1 State and structure of tourism services	0.10	3	0.90
	8.2 Level of the labour force development		3	
	8.3 State of the investment market and investment goods of the stock market		3	
	Final score		9	
9. Political will of the authorities and the legal framework of the state	9.1 Existence of an appropriate legislative and regulatory framework	0.08	3	0.96
	9.2 Stability of the national currency		3	
	9.3 Currency manipulation		3	
	9.4 State of the market of investments and investment goods of the stock market		3	
	Final score		12	
10. State of the financial and credit system and the activities of financial intermediaries	10.1 Investment activities of banks (their level)	0.09	3	0.99
	10.2 Achieving stability of the national currency		2	
	10.3 Investment policy of the national bank		3	
	10.4 Regime of foreign investment		3	
	Final score		11	
11. Status of a foreign investor	11.1 International institutional finance and loans	0.10	3	0.80
	11.2 Free offshore economic zones		3	
	11.3 Relations of transparency in the state		2	
	Final score		8	
Weighted average final score			**7.76**	

Source: own

determining the level of economic and investment activity of the tourism industry in Prague. Using the generalizing indicator – the coefficient of economic and investment activity of the tourism industry, which is calculated according to the following methodology:

$$P_{in} = \sum P_i * W_i = 1.08 + 0.24 + \\ + 0.9 + 0.81 + 0.27 + 0.27 + 0.54 + \\ + 0.9 + 0.96 + 0.99 + 0.8 = 7.76 \quad (6)$$

where: P_{in} – the level of economic and investment activity of the tourism industry in Prague;

P_i – an expert assessment of the use of economic and investment potential of the tourism industry element in Prague (points); W_i – the weighting coefficient of the element of economic and investment potential of Prague.

It is advisable to assess the level of economic and investment activity of Prague on the following scale: from 0 to 5.5 – low level, 5.5 to 8.0 – medium level, from 8.1 to 12.0 – high level. The analysis showed that the city of Prague has a medium level of economic and investment activity (7.76).

The EU has not yet recovered from the COVID-19 crisis, as its investment activity has declined due to the global economic crisis. Therefore, investment revenues are a key component of economic policy in the EU in the long run.

One of them is to use the EU budget's capacity in the form of refundable financial instruments as a meaningful alternative to the principle of redistributive subsidies. The contribution of the InvestEU program should lead to an increase in investment activity in the long term (EUR 15.2 billion to create a guarantee base of EUR 38 billion). It is essential to mobilize a total of EUR 650 billion of investment across the EU by 2027, make a role for the financial market stronger, including for projects of public interest, and a more efficient allocation of the EU budget that will pass the test of the natural market thanks to the payback element (European Committee of the Regions, 2022).

Czechia ranks first in terms of foreign investment. Data results among Central and Eastern European countries are presented by the Government Agency for Foreign Direct Investment (BIDA, 2023). To implement investment projects, CzechInvest supports innovative start-up companies of foreign investors who are just entering the Czech tourism market. An assessment of the social potential of the development of the tourism industry in Prague is presented in Tab. 3.

The final stage of assessing the social potential for the development of the tourism industry in Prague involves determining the level of social activity of the tourism industry in Prague with the help of the generalized indicator – the coefficient of social activity of the tourism industry in Prague, which is calculated according to the following methodology:

$$P_s = \sum P_i * W_i = 1.14 + 1.14 + \\ + 1.47 + 0.9 + 4.83 = 9.48 \quad (7)$$

where: P_s – the level of social activity of the tourism industry in Prague;

Tab. 3: Expert assessment of the social potential of development of the tourism industry in Prague – Part 1

Components	Parameters	Weight	Prague	
			Points (1–3)	Balanced assessment
1. Economically active population	1.1 Of working age	0.19	3	1.14
	1.2 Older than of working age		3	
	Final score		6	
2. Employed	2.1 Of working age	0.19	3	1.14
	2.2 Older than of working age		3	
	Final score		6	
3. Unemployed	3.1 Of working age	0.21	2	1.47
	3.2 Older than of working age		3	
	3.3 Level of registered unemployed (%)		2	
	Final score		7	

Tab. 3: Expert assessment of the social potential of development of the tourism industry in Prague – Part 2

Components	Parameters	Weight	Prague	
			Points (1–3)	Balanced assessment
4. Economically inactive population	4.1 Of working age	0.18	2	0.9
	4.2 Older than of working age		3	
	Final score		5	
5. Efficiency of labour market	5.1 Average salary in the region	0.23	3	4.83
	5.2 Average income level of the population		3	
	5.3 Cooperation in employee-employer relations		3	
	5.4 Flexibility in setting wages		3	
	5.5 Hiring and firing practices		3	
	5.6 Remuneration and productivity		3	
	5.7 Rate and professional management		3	
	Final score		21	
Weighted average final score		**9.48**		

Source: own

P_i – an expert assessment of the use of social potential of the tourism industry element in Prague (points); W_i – the weighting coefficient of the social potential element of the tourism industry in Prague.

It is advisable to assess the level of activity of the social potential of the tourism industry in Prague on the following scale: from 0 to 5.5 – low level, 5.5 to 8.0 – medium level, from 8.1 to 12.0 – high level.

The analysis showed that Prague has a high level of activity of the social potential of the tourism industry (9.48).

Social development in Czechia is facilitated by wide availability of an educated, relatively inexpensive labour force; the reduction of unemployment due to the growth of the migrant labour force; unemployment insurance and other social protection programs for workers dismissed for economic reasons; and increasing wages and living standards. According to the OECD, the Czech Republic is considered to be one of the countries with the lowest poverty and unemployment rates, as well as the lowest income inequality in OECD countries caused by taxes (OECD, 2018).

Despite the improvement in labour productivity, it is lagging behind the OECD average. This is due to the problems associated with the economic downturn during the pandemic. Some innovative developments in the business environment and investment in the industry are not strong enough and are burdensome for tourism development.

The assessment of the scientific potential of the development of the tourism industry in Prague is presented in Tab. 4.

$$P_{sc} = \sum P_i * W_i \tag{8}$$

where: P_{sc} – the level of scientific activity of the tourism industry in Prague; P_i – an expert assessment of the use of scientific potential of the tourism industry element in Prague (points); W_i – the weighting coefficient of the scientific potential.

$$P_{sc} = 0.48 + 1.98 + 1.36 + \\ + 1.36 + 1.6 + 1.6 = 8.38 \tag{9}$$

It is advisable to assess the level of scientific potential of the tourism industry in Prague on the following scale: 0 to 5.5 – low level, 5.5 to 8.0 – medium level, and from 8.1 to 12.0 – high level. The analysis showed that the tourism industry in Prague has a level of scientific potential activity of 8.38.

Tab. 4: **Expert assessment of the scientific potential of development of the tourism industry in Prague – Part 1**

Components	Parameters	Weight	Prague	
			Points (1–3)	Balanced assessment
1. The country's scientific organizations	1.1 The number of organizations performing research by city and region of the country (units)	0.16	3	0.48
	Final score		3	
2. Total number of scientific staff	2.1 Number of employees of scientific organizations	0.18	3	1.98
	2.2.Number of employees performing research in the tourism industry		3	
	2.3. Number of PhDs employed in the tourism industry		3	
	2.4. Number of doctors of science employed in the tourism industry		2	
	Final score		11	
3. Financing of scientific work performed in the tourism industry	3.1 Volume of scientific work performed in the tourism industry, total (thousand CZK)	0.17	2	1.36
	3.2 Expenditures on research and development in the tourism industry (CZK million)		3	
	3.3 Domestic current expenditures on research and development in the tourism industry (CZK million)		3	
	Final score		8	
4. Effectiveness of scientific works performed in the tourism industry (%)	4.1 The number of completed tourism works in the tourism industry (copies)	0.17	3	1.36
	4.2 The number of printed works in the tourism industry (copies)		2	
	4.3 The number of applications for copyright protection in patent offices (copies)		3	
	Final score		8	
5. International activities of scientific organizations	5.1 The number of researchers' trips outside the country (persons)	0.16	3	1.60
	5.2 The number of international conferences organized by organizations (units)		3	
	5.3 The number of grants received for research from international funds (copies)		2	
	5.4 The number of researchers who used the grant (persons)		2	
	Final score		10	

Tab. 4: Expert assessment of the scientific potential of development of the tourism industry in Prague – Part 2

Components	Parameters	Weight	Prague	
			Points (1–3)	Balanced assessment
6. Creation and use of advanced technologies and intellectual property	6.1 The number of advanced technologies created and used in the tourism industry	0.16	2	1.60
	6.2 The number of all inventions and utility models used in production		2	
	6.3 Distribution of authors of intellectual property objects in the tourism industry (units)		3	
	6.4 Distribution of rationalization proposals in the tourism industry (persons)		3	
	Final score		10	
Weighted average final score		**8.38**		

Source: own

The results of assessing scientific potential for the development of the tourism industry in Prague indicate the promotion of tourism infrastructure development in the city and the need to ensure the sufficiency and quality of human capital for R&D.

3.3 Assessment of the integral indicator of the smart specialization potential of the tourism industry in the Czech regions

Having studied the activity of the tourism industry in Prague through the potential of development of innovation, economic and investment, social, and scientific components, the integral indicator of the smart specialization potential was determined to be 8.99. This is a high level on the evaluation scale.

Tab. 5 shows the integral indicator of the potential for smart specialization of the tourism industry by the Czech regions.

Based on the results of the expert assessment, an integral indicator of the smart specialization potential of the tourism industry in the Czech regions was calculated. The integral indicator of the smart specialization potential of the tourism industry in the Czech regions can be ranked as follows: 0 to 5.5 – low level, 5.5 to 8.0 – medium level, 8.1 to 12.0 – high level.

Having calculated the integral indicator of the smart specialization potential of the tourism industry in the regions of Czechia on the basis of statistical data and expert opinion, it was found that the highest indicator of the tourism industry potential is in the city of Prague. Prague has 8.99 points. The lowest indicator was determined in the Pardubice region – 1.72 points. Thus, the integral indicator of the smart specialization potential allows to determine the level of tourism industry development tourism industry in a specific region, to divide regions into groups (clusters) according to the level of the tourism industry development. This makes it possible to determine directions and prospects for the tourism industry development in each region and distribute the amounts of state and grant funding.

3.4 Ways to implement smart specialization in Czech tourism

The development of the Czech economy requires introducing an effective mechanism for achieving positive trends in the competitiveness of the country's regions. International experience has shown that a promising tool for achieving this goal can be smart regional specialization, which consists of a detailed in-depth study of the competitive advantages of a particular territory and, on this basis, a thorough development of an action plan in order to maximize efforts and improve the competitiveness of the region in the chosen area. The study has led to the conclusion that today, in Czechia, it is necessary to control the planned tourism development measures for the studied tourism development strategies in the Czech regions.

The analysis of the volume of investment support for the implementation of Czechia's

Tab. 5: Integral indicator of the potential for smart specialization of the tourism industry by the Czech regions

Czech regions	Integral indicator
Prague (the capital)	8.99
South Moravian	6.67
Hradec Králové	5.04
South Bohemia	5,03
Cantral Bohemia	4.07
Karlovy Vary	3.97
Liberec	3.82
Moravian-Silesian	3.43
Pilsen	2.74
Zlín	2.76
Olomouc	2.51
Vysočina	2.21
Ústí nad Labem	2.00
Pardubice	1.72

Source: own

smart specialization strategy leads to the conclusion that the EU, through a number of programs and projects, constantly supports financially the implementation of smart strategies in Czechia. Czechia's smart development strategy includes a financial budget for annual use, which is distributed according to its intended purpose.

Also, the Czech Tourism Development Strategy for 2021–2030 sets out indicative financial limits for the Czech Strategy implementation at the expense of the MMF budget (one year), see Tab. 6.

According to Research, Development and Innovation Council (2019), the estimated allocation of Czech travel agencies for tourism development in Czechia for the year is CZK 562 million (euro exchange rate 25.295 on January 15, 2025; Czech National Bank). The integral indicator of the potential of smart

Tab. 6: Estimated financial support for the implementation of Czechia's Smart Strategy at the expense of the MMF budget for 2021–2027

Priority headings/ measures	Allocation for strategy implementation in CZK million/year* MMR budget
Utilizing intellectual solutions in data sharing, information sharing, best practice examples	11
MIS 1	1
Connecting DMO and MIS information systems/e-tourist (one-time cost)	5
Conferences (e.g., TTD, Cr Forum, 360°), seminars, workshops, educational events, exchange of experience	5
Total	**22**

* Euro exchange rate 25.295 on January 15, 2025 (Czech National Bank)

Source: Ministry of Industry and Trade (2021)

specialization of the tourism industry by regions of Czechia allows for optimization of the distribution and redistribution of funding by region. Regions with a low value of the integrated indicator of the tourism industry smart specialization potential need additional research on improving the tourism industry state in the region and additional funding if necessary.

Therefore, the main ways to introduce smart specialization in the Czech tourism industry are as follows: i) financing and support for the implementation of smart strategies in Czechia; ii) creating modern business models with the right regulatory framework; iii) use of modern digitalization, support of citizens by the government according to the theory of change; and iv) providing infrastructure in accordance with standards for the development and effective operation of smart solutions (But et al., 2023).

Smart specialization technologies will increase the tourism potential of Czechia and increase its competitiveness in the tourism market.

3.5 Discussion

Thus, the study results in determining the impact of smart specialization on the Czech tourism industry development using the integral indicator of smart specialization potential. The results obtained indicate the key elements of the tourism industry development under the influence of smart specialization.

As defined above in the theoretical part of the study, scientists have determined that smart specialization in the tourism industry and the economy in general should be based on due consideration of environmental issues (But, 2024a; Šulyová & Kubina, 2022).

The use of smart specialization in European cities is associated with the interconnection of regional authorities with the population, which improves the quality of the urban areas and their impact on the environment (Adamuscin et al., 2016). Such changes are occurring against the backdrop of economic and technological changes caused by the processes of integration and globalization, which are the common challenges that have to be faced in the context of competitiveness and sustainable development of cities.

Using innovative efforts of smart specialization through developed "smart" cities such as Barcelona, Rotterdam, and Vienna, it is indicated to pay attention to the negative changes of climate action. It is necessary to put the environment at the center of development, to protect the smart infrastructure from the impact of climate. There is a growing need to evolve a "smart city" into a "smart sustainable city" by taking into account the interaction between technology and nature, which will facilitate the integration of climate strategies and encourage citizen participation, which is crucial (Fernández & Peek, 2020).

The impact of smart specialization policies is shown in the study by Vanolo (2013). The discourse of the smart city can be a powerful tool for creating compliant subjects and mechanisms of political legitimization. A new vision of smart specialization and the role of private entities and citizens in urban development management is being developed.

Improving the efficiency of management, the quality of life of residents, and tourist experiences is possible through an intelligent approach applied to the processes related to public administration and planning of tourist cities (Ivars-Baidal et al., 2023).

Panyadee et al. (2023) also pointed out that smart specialization innovations are used to improve or assist the ecotourism management system at the destination. At all stages of the journey, technology-based tourism experiences are increasingly helping travellers to co-create values. Ambient intelligence (AmI) tourism is being developed by several new technologies. In addition, technological developments are bringing together a wide variety of stakeholders in the travel industry. Thus, smart technologies help determine the strategic directions of tourism enterprises and their competitiveness.

Thus, a number of problems affect the effectiveness of smart specialization in the Czech tourism industry, namely: i) imperfect legislation; ii) lack of qualified human resources at the municipal level, outdated urban infrastructure, lack of investment for sustainable development of the industry; iii) 50% of the population is not familiar with available mobile applications that improve the quality of life; and iv) the sufficiency and quality of human capital for R&D.

Therefore, we can state that the development potential of the Czech tourism industry depends on the interaction of local assets, potential markets, social challenges, business, and politics. The development of the Czech tourism industry is based on the revival of the ecosystem, the development of rural and peripheral regions, the wise use of information and communication

technologies, innovative strategies, a qualified regional labour force, knowledge, increased cooperation between different levels of government and stakeholders, and mechanisms of political legitimization in urban development management.

Further research will be aimed at creating a multidimensional strategy capable of utilizing the knowledge-intensive dynamics of cooperation within the EU's Neighbourhood Policy to introduce innovations in the "smart" tourism sector.

Conclusions

Based on the results of the study, the potential for the development of the Czech tourism industry on the basis of smart specialization is assessed. At the same time, a methodological approach is proposed using an integral indicator of the potential of smart specialization. This indicator is based on the results of assessing the social, economic and investment, scientific, and innovative potentials of the tourism industry in Czechia. The expert assessment has shown a high level of activity of the tourism industry in Prague due to its innovative, economic, investment, social, and scientific potentials.

The results of assessing the integral indicator of the smart specialization potential of the tourism industry in the regions of Czechia allow comparing the performance of individual regions within the tourism industry, the indicators of the industry development with the indicators of individual regions and allow to optimize the distribution and redistribution of funding by region. It is determined that the smart specialization potential of the tourism industry in Prague is high. The smart specialization potential of the tourism industry in the South Moravian, Hradec Králové, and South Bohemia regions is of an average level. The tourism potential of the remaining regions is low.

In addition, the integral indicator of smart specialization potential can be used as a tool for allocating investment resources to ensure the development of the Czech tourism industry and its regions. Regions with a low value of the integrated indicator of the tourism industry smart specialization potential need additional research on improving the tourism industry state in the region and additional funding if necessary.

The ways of introducing smart specialization into the Czech tourism industry, which will help to improve the country's image in order to attract tourists, are identified: i) financing and support for the implementation of smart strategies in Czechia; ii) creating modern business models with the right regulatory framework; iii) use of modern digitalization, support of citizens by the government according to the theory of change; and iv) providing infrastructure in accordance with standards for the development and effective operation of smart solutions.

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Twenty years of efficiency research in Czech and Slovak banking – A bibliometric analysis

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Abstract: *The article is a survey of 44 empirical studies that applied frontier techniques in analyzing efficiency of Czech and Slovak commercial banks in a hope to summarize the state of the art of efficiency research in Czech and Slovak banking. A sample of 44 journal articles was extracted from the Web of Science™ database, and a bibliometric analysis was conducted to identify the most active authors and most influential works to establish mutual relationships between them and to sketch the main research trajectories. The paper contributes to the extant literature by providing guidance for new researchers and identifying for efficiency research on Czech and Slovak banking: (i) the most productive authors as well as the works with the most impact; (ii) the network structure amongst the authors and works; and (iii) main paths of knowledge diffusion across the surveyed works. The findings indicate that efficiency research of Czech and Slovak banks grew out of global banking efficiency research and is thus its integral part. Lotka's law applied to Czecho-Slovak banking efficiency research does not suggest that its productivity patterns are altogether different from its global counterpart. The first identifiable wave of research was represented by foreign authors who examined issues of economic transition and its impact on the performance of banks. This wave of research endured until about 2013, when the torch passed into the hands of authors of domestic provenience. The findings are useful in bridging the gap between the accumulated knowledge in the field and the new research directions.*

Keywords: *Banking efficiency, Czech banks, Slovak banks, research trajectory, bibliometric analysis.*

JEL Classification: *G21, L25.*

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Introduction

The upsurge of banking efficiency as a central topic of analytical and empirical literature in the past four decades (Berger & Humprey, 1997; de Abreu et al., 2019; Duygun-Fethi & Pasiouras, 2010) has four major reasons. A first reason is the fact that the concept of efficiency builds on microeconomic foundations, and understanding it only requires taking an elementary course in economics. A second reason is that efficiency is a concept that puts an activity or unit (such as a bank) into a direct confrontation with an optimal situation. A third reason is that the concept of efficiency is easily usable even in complex situations when several performance factors (such as inputs, outputs, and operating variables) must be considered simultaneously. Finally, a fourth reason is that econometrics and operations research have provided efficiency measurement with

fully fledged and sound tools that are adjustable to particular situations.

The contemporary Czech and Slovak banking sectors have been operating in market conditions since the early 1990s, and in the first decade of their renewed market existence, they had to struggle with extensive banking reforms aimed at securing their survival and stability after the damage caused by both the initial undercapitalization and the absence of prudential regulation. Having been solidified with the turn of the new millennium, the early 2000s became the landmark when more serious academic research sprang out to investigate the issues of performance, competitiveness, stability, liquidity and capital adequacy of Czech and Slovak commercial banks. The first academic studies took form of international comparisons and were originated by foreign authors that explored the legacies of economic transition and the effects of ownership upon performance of Czech and Slovak banks in confrontation to banks in other transition economies or to western banks. Only in their wake came domestic authors with a focus specialized mostly upon Czech and/or Slovak commercial banks or possibly their branches. A body of empirical literature has arisen in which efficiency has become synonymous with performance, partly understood in a multitude of forms. Efficiency as a major object in banking academic research has presently stepped down in favour of a more diversified portfolio of research interests such as macroprudential regulation and financial stability, and the initial efficiency-related research front has become saturated.

Based upon a selection of 44 journal articles extracted from Web of Science™ that are thematically devoted to efficiency measurement in Czech and Slovak banking, this paper performs a bibliometric analysis of the main works that have shaped and advanced knowledge on the efficiency of Czech and Slovak banks. The exploration relies entirely on articles published in journals with a peer-review process, and excludes conference papers that are generally known to be of lesser quality, although their presentation before a wider audience was effective in the diffusion and dissemination of knowledge amongst Czech and Slovak researchers who took up the initiative in the last decade. The exploration covers articles published in the past two decades between 2002 and 2022, and the paper contributes to the extant literature by identifying for banking research on Czech and Slovak banking: (i) the main research fronts followed by the authors; (ii) the most productive authors as well as the works with the most impact; (iii) the network structure amongst the authors and works, and main paths of knowledge diffusion across the surveyed works. These interests facilitate a general view of the research field on Czecho-Slovak banking efficiency, and their coverage ranges from performance analysis (ii) to science mapping (i, iii). Being two basal methodologies in bibliometrics, performance analysis measures the position of the field in terms of scientific outputs, science mapping outlines the relationship between authors, citations and the flow of information amongst the authors (Öztürk et al., 2024). Inter alia, bibliometric analysis can be instrumental in identifying research gaps (Fergnani, 2019), and this is also anticipated of the current bibliometric survey: to wit, to identify underexplored elements of efficiency research.

With a geographical focus upon two post-Socialist and post-transition economies, the operating space is admittedly much narrower than that available for studies with a global focus (e.g., Berger & Humphrey, 1997; de Abreu et al., 2019; Duygun-Fethi & Pasiouras, 2010). Nonetheless, the outcomes of the study are not only suited to researchers interested in Czech and Slovak banks alone. More importantly, they also provide first guidance to those scholars who wish to study the effects of transitional and consolidation reforms in a particular set-up of post-Socialist countries that lived in a multinational federation and split up peacefully to follow a path of European integration after a decade. Albeit it was not sort of uncommon for multi-national states in the Eastern Block to dissolve (Bunce, 1999), this is a rare case when the process of disintegration was not violent, and was later crowned by joining a project of a higher economic integration. Hence, that this paper considers Czech and Slovak banking simultaneously is but natural given the fact that both banking sectors shared their history until the end of 1992, and after the split in 1993 they had to undergo a series of similar reforms. Whereas roughly the first decade of the surveyed portfolio of articles is concerned with the transition experience, the second decade is more engaged in monitoring the effects of European integration.

Aside from their shared political and socio-economic history until 1993, Czechia and Slovakia represent an interesting case study in and of themselves. As also echoes amongst the analytical outcomes of the present study, both banking sectors experienced in the 1990s a painstaking transformation process, and extensive changes were undertaken in multiple areas. They aimed at the consolidation in order to remove classified loans from balance sheets of commercial banks and strengthen capital adequacy, and they also aspired to improve the ownership structure through privatization and inviting the entry of foreign capital in the hope of acquiring new know-how from foreign investors (Medveď et al., 2012). Given the small size of both banking sectors, both banking sectors were constructed as small nets of universal banks that would provide a range of services to their customers without a particular emphasis on specialization (Šestáková & Ferenčíková, 2015). A consequence is that both banking sectors share a similar banking structure (Cienski, 2011) that remain relatively highly concentrated, with 5-bank concentration ratios remaining across 1993 to 2021 at an average 75% for Czechia and 90% for Slovakia (World Bank, 2022). Nonetheless, they are both underbanked compared with western Europe, which is then reflected in their relatively low deposit-to-gross-domestic-product and loans-to-gross-domestic-product ratios (World Bank, 2022). Czech and Slovak banks tilt towards conservative models with an emphasis upon the domestic retail and corporate segments, which is also the reason that they were never seriously hit by the Global Financial Crisis as they had not participated in innovative products (Cienski, 2011). The abstinence of highly risky business engagements was a natural consequence of their enjoyably high level of liquidity that has remained to date (European Commission, 2024; Palečková & Klepková Vodová, 2021). Although the banking sectors of Czechia and Slovakia have many striking similarities, and both countries joined the European Union in the same year, their economies have, in fact, taken different reform paths with differently timed measures. In this respect, Slovakia is evaluated as extraordinarily pro-reformist and the implemented reforms attracted capital inflows and helped the re-orientation of Slovakia to western markets, which was also aided partly by the euro adoption in 2009 (Horská & Prega, 2023). For these reasons, comparisons of efficiency of Czech and Slovak banks are likely to remain perennial challenges also in the future research.

The field has progressed considerably since the last survey on banking efficiency in Central or Eastern European (CEE) countries by Banerjee (2012). With a greater and updated selection of articles, the present paper may be envisioned to ignite this sort of interest specialized to a territorial selection of countries where specific topics such as those linked with economic transition or bank competition are of paramount importance in addition to otherwise standard performance assessment of banks.

The remainder of the paper is organized into three more sections. Section 2 gives details on the compilation of the surveyed papers. The results of the bibliometric analysis are presented in Section 3. The last Section 4 discusses and concludes.

1. Data

For economics fields, there are three basic sources to identify relevant publications for state-of-the-art surveys and bibliometric analyses: Web of Science™ (currently maintained by Clarivate PLC, Pennsylvania, USA), Scopus® (provided by Elsevier B. V., the Netherlands) or Google Scholar (operated by Google LLC, California, USA). Of these, the first two are citation databases provided as a paid service and are fully recognized in the academic community; whereas the last one is a freely accessible web search engine that emulates the functions of full-text and citation databases and has only a complementary status. Albeit none of them can be claimed to have full coverage and different strategies were implemented to identify relevant documents to review and analyse (e.g., Banerjee, 2012; Fall et al., 2018; Kaffash et al., 2020; Kumar & Gulati, 2014; Liu et al., 2013), Web of Science is certainly most comprehensive and is chosen here as the main source.

With reliance upon Web of Science, a two-stage procedure was applied at the end of February 2022 to select the set of 44 journal articles. The list of the selected articles is reported at the end of the concluding section. Only journal articles that presented (solely or predominantly) applied research in bank efficiency in Czechia or Slovakia using a frontier method were

qualified for this survey. Five approaches have been counted amongst frontier methods as they have profiled themselves over the years in banking efficiency literature (Banerjee, 2012; Berger & Humphrey, 1997; Kumar & Gulati, 2014): stochastic frontier analysis (SFA), the distribution-free approach (DFA) and the thick frontier approach (TFA), data envelopment analysis (DEA), and free-disposal hull (FDH).

In the first stage, a search in the Web of Science Core Collection was conducted in the abstracts, keywords and titles of documents for search words filtering the output related to: (i) banking; (ii) efficiency; (iii) Czechia or Slovakia. Different combinations were successively employed; to wit: efficiency Slovak banks/banking, efficiency Czech banks/banking, bank/banking efficiency Slovakia/Czechia, bank/banking efficiency Slovak/Czech Republic. The search targeted only journal articles (either published or in the early access stage) and data papers. Conference papers were not included in the search inasmuch as only rigorously peer-reviewed scientific output was intended for the survey. Conference proceedings typically organize research output with preliminary results and are notorious for their varying quality. Subject to exclusion was also other publication output such as working papers, research reports, monographs or chapters in edited monographs, dissertations. Such an exclusion of minor research output is in tune with best practices in state-of-the-art and bibliometric surveys (e.g., Banerjee, 2012; Duygun-Fethi & Pasiouras, 2010; Kaffash et al., 2020). The initial search returned a list of 324 candidate articles, which were screened by examining their titles and abstracts and reviewing their contents for compliance with the qualifying criteria. This narrowed the initial list to 44 articles (the full list is provided at the end of the concluding section). The qualifying criterion of applied research turned out to be crucial in distinguishing purely methodological developments (reposing in this case on DEA) illustrated on Czech or Slovak banks or bank branches from papers that contribute to understanding efficiency in Czech and Slovak banking. Nonetheless, the stipulation that an article be included in Web of Science caused that some articles slipped the survey (e.g., Stavárek, 2005b), which may pose some limitations on the scope of the survey.

The analysis in this paper is based not only on individual papers, but also on their full bibliographic records available and downloaded from Clarivate's Web of Science (especially citations and journal citation metrics). This bibliometric analysis ensues in the next section. Some summaries of the bibliographic data extend purely quantitative information on authors and their published output by additional qualitative information on the journals that published the surveyed efficiency research on Czech and Slovak banks. Specifically, the quality of journals is represented by two journal metrics extracted from Clarivate's Journal Citation Reports™ for 2021, which is the latest available year in the time of writing this survey. Insomuch as for a good many journals their journal impact factors were not available, two less known, if more refined, journal metrics are utilized instead; to wit, the Article Influence Score™ (AIS) as well as the normalized Eigenfactor™ Score (nEF). Both metrics are intended to capture the prestige of a journal in the scientific community and are an improvement upon the journal impact factor (Bergstrom et al., 2008). Whilst they are constructed in such a way that an average journal has an AIS of 1.00 and/or an nEF of 1.00, a rough difference between them lies in that that the former gauges the importance per article, and the latter the importance of all articles published in the journal. Their advantage, amongst others, is in their review time frame since they monitor and aggregate citation impact for a five-year period.

2. Bibliometric analysis

The present analysis of scholarly literature on efficiency of Czech and Slovak banks serves a three-fold purpose. First, it seeks to establish productivity and citation patterns detectable in the surveyed empirical literature. Second, it strives to outline and determine relationships amongst the authors and articles. Finally, it aspires to highlight main flows of knowledge diffusion amongst the articles.

The survey comprises a total of 44 articles, authored or co-authored by 63 researchers who produced an average 1.508 ± 1.311 articles on banking efficiency spotlighting at least marginally Czech or Slovak banks. Whereas every article was written by one to five authors, most of these articles were originated by a single author or by a pair of authors, which were 17 articles in either case. Subsequently, 6, 3, and 1 published articles were written by three, four and five authors. Only three researchers

published each article of theirs alone, and as many as 5 articles arose in this self-reliant fashion (i.e., Palečková, 2017, 2019; Stavárek, 2005a, 2006; Svitálková, 2014). Despite the fact that the language was not a selection criterion, almost all the surveyed articles were written in English, and only 6 articles were published in a different language. Specifically, 4 articles were published in Slovak (Baruník & Soták, 2010; Boďa, 2019; Kočišová, 2012, 2014b), and there were per one case of an article written in Czech (Stavárek, 2005a) and French (Weill, 2006).

The articles included in the survey were published in 27 different scholarly journals and their distribution points to an extremely low level of concentration in these journals. Tab. 1 reports 13 academic journals that published more than one paper and their catalogue comprises 6 periodicals that are operated by publishers located in the CEE area. It is but understandable that unless an article is shaped as an extensive comparative study across a range of countries, its international reach is rather limited, and its authors are likely to face troubles with finding an appropriate outlet for their research. It is then easy to surmise that the reach to an international audience and knowledge diffusion may be notably restricted. This unfortunate bias is also attested by the fact that top-quality journals are not particularly listed. For instance, only two journals are tagged in Tab. 1 with an above-average AIS or an average nEF. For the 27 target journals of Czecho-Slovak banking efficiency research, these averages for 2020 were

Tab. 1: Target journals with at least two published articles

# articles	Journals
4	Ekonomický časopis, Comparative Economic Studies, Journal of Banking & Finance†/‡
2	Acta Oeconomica, Acta Polytechnica Hungarica, E&M Economics and Management, Eastern European Economics, Economic Change and Restructuring, Economics of Transition†, Finance a úvěr – Czech Journal of Economics and Finance, Politická ekonomie

Notes: The symbols † and ‡ in superscripts denote journals whose AIS or normalized eigenfactor score, respectively, is above average amongst the 29 journals that provided publication outlets of efficiency research in Czech and Slovak banking.

Source: own

0.371 and 0.540, respectively. The distribution of journal metrics for the 27 target journals is extremely right-skewed.

Unlike other similar recent surveys (e.g., Bhukya et al., 2022; de Abreu et al., 2019; Kaffash et al., 2020), this analysis handles productivity and citations of individual authors not only in the sense of gross counts, but also in the sense of their co-authorship shares. These concepts coincide with what Perianes-Rodriguez et al. (2016) call full and fractional counting, respectively, albeit their terminology arises in construction of bibliometric networks. If an article emerged from a collaborative effort of n authors and has received k citations, with full counting each author is assigned for the given article a count of 1 and a full number of k citations. In contrast, under fractional counting each author is attributed only a $1/n$-th of an article with k/n citations. Certainly, it would be ideal to allocate the count and citations amongst the authors in proportions in which they contributed to the writing of the article, but this information is not normally available.

The most prolific authors are reported in Tab. 2 and their report is restricted to the authors whose number of published works for full and fractional counting is above average. For most authors, going from full counting to fractional counting does not affect much their relative position in the ranking. In terms of the quantity of published articles, the most prolific authors are those of Czecho-Slovak provenance (K. Kočišová, M. Boďa, E. Zimková, I. Palečková, D. Stavárek) plus an author of French provenience (L. Weill).

Tabs. 3–4 give a list of the most cited articles and the most cited authors. For articles, two aggregate citations metrics are displayed;

Tab. 2: Ranking of the prolific authors

Full counting			Fractional counting		
Rank	**Name**	**Count**	**Rank**	**Name**	**Count**
1–2	K. Kočišová	7.00	**1–2**	K. Kočišová	5.33
	L. Weill			L. Weill	
3	M. Boďa	6.00	**3**	M. Boďa	4.00
4	E. Zimková	3.00	**4–5**	I. Palečková	2.00
5–14	A. M. Andrieș	2.00		D. Stavárek	
	J. P. Bonin		**6–8**	A. M. Andrieș	1.50
	I. Hasan			A. Kasman	
	A. Kasman			E. Zimková	
	J. Lešanovská		**9–10**	J. Podpiera	1.00
	I. Palečková			Z. Svitálková	
	J. Podpiera		**11–12**	J. Lešanovská	0.83
	A. Pruteanu-Podpiera			A. Pruteanu-Podpiera	
	D. Stavárek				
	P. Wachtel				

Source: own

to wit, total citations and citations per year. Citations per year follow from dividing total citations by the number of years that have elapsed since official publication determined by the formula max {2022 − publication year, 1}, where the maximum makes amends for Moudud-Ul-Huq et al. (2022). For authors, citations are considered in measurements arising from full and fractional counting. Tab. 3 exhibits the top 10 most cited surveyed articles in total or per year. Apparently, citations per year is a better metric of impact for fresher publications that have not had an opportunity to attract sufficient attention as yet than older articles. Moving from total citations to citations per year only induces a slight permutation in the position of the eight first articles and updates the articles at positions 9 and 10. Useful information is that an article in the survey during its life generated on average 45.591 ± 94.351 citations altogether and 3.464 ± 5.807 citations per year, which demonstrates a good scientific impact of the articles reported in Tab. 3, leastwise in comparative terms. Simultaneously, the high standard deviations attest to high heterogeneity in citations amongst the authors. The most cited positions are occupied by cross-country studies whose research agenda focused upon banking efficiency in transition economies. These studies were first to explore the effects of transition reforms (Fries & Taci, 2005), ownership (Bonin et al., 2005a; Fries & Taci, 2005; Weill, 2003), privatization (Bonin et al., 2005b) or to perform extensive comparisons of banking efficiency whilst identifying drivers of efficiency (Grigorian & Manole, 2006; Kasman & Yildirim, 2006). Exceptions are Podpiera and Weill (2008) who sought connections between banking efficiency and non-performing loans with a focus on Czech banks only, and Balcerzak et al. (2017) who assessed the efficiency of 28 European Union banking sectors. Tab. 4 resembles Tab. 3 and comes almost as its transposition by listing the 11 most cited authors identified by full as well as fractional citation counts. The average number of citations per author amongst the surveyed works was 82.105 ± 157.765 citations under full counting and 35.193 ± 64.140 citations under fractional counting, so Tab. 4 contains safely above-average cited researchers. A notable aspect behind the lists in Tab. 4 is that their positions are occupied by pioneers on the topic of banking efficiency in transition countries, to Czecho-Slovak conditions foreign authors who made an early contribution to this fledgling

research area. Their publication at the inception of this research front in applied economics in journals of good standing ensured them accelerated citations, albeit some of them have had only one shared research output (S. Fries, A. Taci, C. Yildirim, V. Manole, D. A. Grigorian) or two shared publication outputs (J. P. Bonin, I. Hasan, P. Wachtel, A. Kasman, J. Podpiera).

Tab. 3: Ranking of the most cited articles

Total citations			Citations per year		
Rank	**Article**	**# citations**	**Rank**	**Article**	**# citations**
1	Bonin et al. (2005a)	472	**1**	Bonin et al. (2005a)	27.765
2	Fries and Taci (2005)	385	**2**	Fries and Taci (2005)	22.647
3	Bonin et al. (2005b)	172	**3**	Balcerzak et al. (2017)	16.000
4	Weill (2003)	141	**4**	Bonin et al. (2005b)	10.118
5	Kasman and Yildirim (2006)	112	**5**	Podpiera and Weill (2008)	7.643
6	Podpiera and Weill (2008)	107	**6**	Weill (2003)	7.421
7	Grigorian and Manole (2006)	105	**7**	Kasman and Yildirim (2006)	7.000
8	Balcerzak et al. (2017)	80	**8**	Grigorian and Manole (2006)	6.563
9	Pruteanu-Podpiera et al. (2008)	63	**9**	Matoušek et al. (2015)	5.000
10	Andrieș (2011)	37	**10**	Havránek et al. (2016)	4.833

Notes: Only citations in the Web of Science Core Collection are taken into account. Nonetheless, calculating with citations in all Web of Science databases will not affect the reported ranking.

Source: own

Tab. 4: Ranking of the most cited authors

Full counting			Fractional counting		
Rank	**Authors**	**# citations**	**Rank**	**Authors**	**# citations**
1–3	J. P. Bonin	644	**1**	L. Weill	250.000
	I. Hasan	644	**2–4**	J. P. Bonin	214.667
	P. Wachtel	644		I. Hasan	214.667
4–5	S. Fries	385		P. Wachtel	214.667
	A. Taci	385	**5–6**	S. Fries	192.500
6	L. Weill	346		A. Taci	192.500
7	A. Kasman	126	**7**	A. Kasman	70.000
8	J. Podpiera	116	**8**	J. Podpiera	58.000
9	C. Yildirim	112	**9**	C. Yildirim	56.000
10–11	D. A. Grigorian	105	**10–11**	D. A. Grigorian	52.500
	V. Manole	105		V. Manole	52.500

Notes: Only citations in the Web of Science Core Collection are taken into account. Nonetheless, calculating with citations in all Web of Science databases will not affect the reported ranking.

Source: own

In this respect it is only L. Weill that sticks out by having produced 9 surveyed articles, out of them five in collaboration.

Needless to say, the tabular presentation in Tab. 2 and Tab. 4 gives a list of leading authors in the field who cannot be ignored when preparing a research study on the efficiency of Czech and Slovak banking. Likewise, Tab. 3 provides a catalogue of canonical works that introduced methodological standards into the field.

In order to summarize aptly the productivity of efficiency research on Czech and Slovak banking, Lotka's constant is estimated and confronted with the values that are typical for finance literature. Lotka's law is an empirical regularity formulated first by Lotka (1926) and later generalized (Chung & Cox, 1990) that has been employed to describe the frequency of publication output in any subject area. It fits remarkably well across different scientific fields (e.g., Nicholls, 1986) and posits the following relationship for the number of authors who have published the same number of papers in the given area: $n^c \cdot a_n = a_1$. It states that the number of authors, a_n, who have produced n papers is n^c-proportional to the number of authors, a_1, who have published just one paper, and this equation is just a restatement of a power-law pattern whose intensity is governed by the constant c. Rearranging the generalized Lotka's equation yields a regression model $\log(a_n/a_1) = -c \cdot \log(n) + \varepsilon$, where: ε is a random error. The regression output presented in Tab. 5 declares an excellent fit and shows the estimated value of Lotka's constant at 1.977, which is not different from values ranging from 1.95 to 3.26 for general finance research reported by Chung and Cox (1990) or from an average value of 1.872 for accounting research estimated by Chung et al. (1992). In a similar vein, this number is comparable to the value of Lotka's constant estimated for banking efficiency research by de Abreu et al. (2019) at 2.304. Unfortunately, de Abreu et al. (2019) have in their reported Tab. 7 a glaring mistake, indicating a value of 4.846 for c. In contrast, the original data in Tab. 6 point to a value of 2.304. Hence, in spite of its narrow geographical focus, research on efficiency of Czech and Slovak banks in terms of productivity is not found altogether different from general or global finance research. The estimated coefficient c matches the original value 2 suggested by Lotka (1926) and proves that this subject area has been dominated by a few researchers. Indeed, the publication output is concentrated amongst

Tab. 5: Regression of the generalized Lotka's law

Estimate of c	Standard error	*T*-statistic	*P*-value	R^2	# observations
2.055	0.166	12.361	<0.001	0.921	5

Notes: The reported R^2 is computed by a formula recommended for a regression model without intercept (e.g., Kozak & Kozak, 1995). The conventional 95% confidence interval for the productivity constant c is [1.594, 2.517].

Source: own

a handful of researchers who found the topics related to Czech and Slovak banking efficiency attractive and worth of pursuit.

After this initial bibliometric assessment oriented on publication and citation productivity, attention is turned to detecting and describing relationships between the authors and articles through bibliographic coupling and co-citation networks. Both these concepts are intended to capture likeness or interconnections between published papers and scholars. Whereas bibliographic coupling refers to the number of references shared by two documents, co-citation represents the frequency with which two documents are cited together. Two documents that cite the same reference are likely to be similar (bibliographic coupling); and this reasoning also applies to a converse situation: two documents that are both cited by a third document are likely to be similar (co-citation). Zupic and Čater (2015) discuss the advantages and disadvantages of both bibliographic mapping methods in detail. Perianes-Rodriguez et al. (2016) recommend accounting for co-authorship of publications in co-citation and other bibliometric analyses by stating that fractional counting is expected to provide more trustworthy results. Two bibliographic coupling networks and two co-citations networks are produced here for the surveyed

articles with the use of the VOSviewer software, version 1.6.17 (van Eck et al., 2010; van Eck & Waltman, 2010), by following fractional counting, when applicable. Fig. 1 displays bibliographic coupling networks for articles and for authors, and Fig. 2 does this for co-citation networks for references and authors. Circle size embodies relative importance and link size represents interconnection strength.

It is not directly visible in the bibliographic coupling network for articles in Fig. 1, but there are four main clusters of articles citing similar research. That said, the cluster formed of Bonin et al. (2005a,b) as well as Fries and Taci (2005) is clearly detectable and populated by studies with similar references. This is the strand of literature occupied with disentangling effects of transition reforms and ownership restructuring from banking efficiency. The other three clusters are around Weill (2003), around Balcerzak et al. (2017), and around Andrieș (2011), respectively. The bibliographic coupling network for authors in Fig. 1 is more a co-authorship network with authors who typically publish in collaboration. There are five clusters of authors whose references overlap with other authors. Articles authored or co-authored by K. Kočišová, M. Boďa, L. Weill cite similar research works. Amongst the four clusters, one cluster consists of K. Kočišová, A. M. Andrieș, I. Palečková, a second cluster is made up of J. Bonin, I. Hasan and P. Wachtel, and a third cluster is formed by M. Boďa and E. Zimková.

Perhaps more revealing is the study of the co-citation networks in Fig. 2 that present references and authors that are cited most frequently. Amongst the cited references are seminal masterpieces of the founding fathers of DEA, M. J. Farrell, A. Charnes, R. D. Banker, or W. W. Cooper; the pivotal paper on SFA by D. J. Aigner, C. A. K. Lovell and P. Schmidt; canonical studies on theory of banking production by C. W. Sealey and J. T. Lindley, A. N. Berger and L. Mester, or P. W. Bauer; first applications of DEA in the banking industry by H. D. Sherman and F. Gold, or J. M. Pastor, and the first authoritative survey on efficiency measurement in banking by A. N. Berger and D. B. Humphrey. The network also contains Bonin et al. (2005a) and Fries and Taci (2005), two early studies on banking efficiency in transition economies that are part of this survey as well. This graph is dominated chiefly by methodological DEA and SFA papers and SFA banking applications. Likewise, concerning the co-citation network for authors, amongst the cited authors are two clusters, which are perhaps not ideally separated. One cluster is DEA-related, whereas the other is SFA-related. The DEA-related block is primarily populated by key figures in DEA methodology R. D. Banker, A. Charnes, W. W. Cooper, R. Färe, and K. Tone, but also contains C. W. Sealey

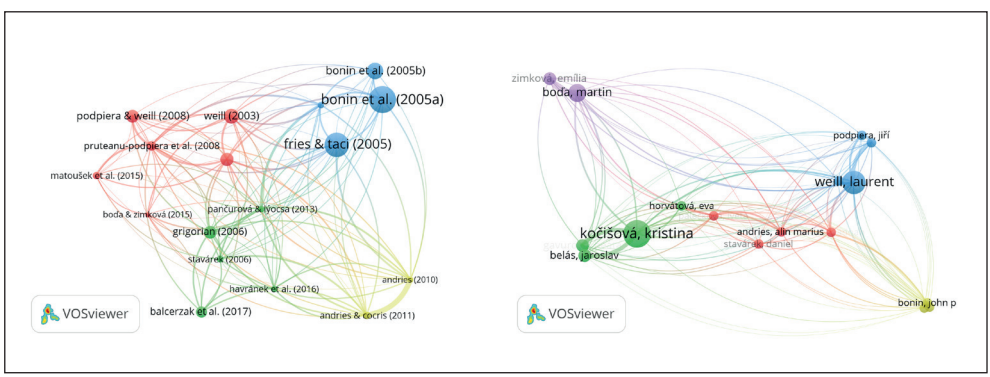

Fig. 1: Bibliographic coupling network for articles and authors

Note: In constructing the network for articles, a threshold of 18 citations at least for an article was applied, which reduced the number of articles to 17. Similarly, for an author at least 2 articles were required, which reduced the number of authors to 16. Fractional counting of Perianes-Rodriguez et al. (2016) was applied in either case.

Source: own

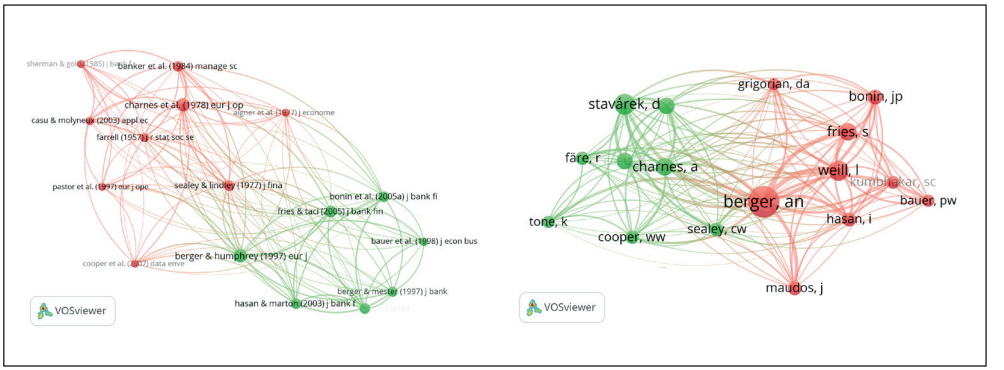

Fig. 2: Co-citation network for references and authors

Note: In constructing the network for references, a minimum of 8 citations for a cited reference was set, which produced a network of 16 references. Likewise, for an author at least 12 citations were required, which reduced the number of authors to 12. Fractional counting of Perianes-Rodriguez et al. (2016) was applied in either case.

Source: own

alongside two empirical economists B. Casu and D. Stavárek. These last two co-cited authors feature for their DEA analyses. In contrast, the SFA-related block is formed of applied researchers included in the survey, J. P. Bonin, S. Fries, I. Hasan, L. Weill (of the seven articles authored or co-authored in the survey, as many as six are based on SFA or DFA), SFA theorist S. C. Kumbhakar and applied stochastic frontier econometrist J. Maudós. Nonetheless, the SFA-related block encompasses also theorists of banking production A. N. Berger and P. W. Bauer (who are closer to SFA than to DEA).

Ultimately, as the preceding analyses have failed to identify the trajectories by which new ideas developed, methodological advances were communicated and knowledge spread across the surveyed articles, main path analysis is conducted in order to uncover these otherwise missed trajectories of historical knowledge diffusion in efficiency research on Czech and Slovak banks. The foundations of main path analysis were laid by Hummon and Doreian (1989), and the method was later refined by Batagelj (2003) and Liu and Lu (2012). Hummon and Doreian (1989) developed first search algorithms applicable to citation networks, Batagelj (2003) proposed an enhanced metric to measure the significance of knowledge dissemination between articles, so-called search path count (SPC), and Liu and Lu (2012) improved on algorithms to search for most significant paths by introducing global and key-route searches. The central idea is to transform a binary citation network into a weighted citation network in which the importance of links between articles is represented by traversal counts measuring how often knowledge passed from first to recent works on the topic whilst traversing through referred and citing articles. When all such possible paths are counted between two articles, their link's SPC is obtained. Global search simply selects a trajectory through articles in the network that maximizes the sum of traversal counts, perhaps subject to the requirement that links with high traversal counts are represented. These are called key routes. Liu and Lu (2012) or Liu et al. (2013) give a full description of these building blocks.

Fig. 3 exhibits the global main path that was selected by including four main key routes. The Pajek software, version 5.14, was employed to identify the global main path and make the graph (de Nooy et al., 2018). The main path is made up of 10 articles, and is initialized with the oldest two papers included in the survey by Weill (2002, 2003). At Weill (2003) the trajectory splits into two different streams: through Kasman (2005) to Kasman and Yildirim (2006), and through Fries and Taci (2005) to Grigorian and Manole (2006). The division implies that Weill (2003) did inspire both lines of research, but these proceeded

without mutual dissemination and unknowingly. Both lines combine in Pančurová and Lýocsa (2013). The chief research agenda of the first works Weill (2002, 2003), Kasman (2005), Fries and Taci (2005) was the effect of restructuring, ownerships on banking efficiency in transition economies, but gradually this emphasis attenuated with Kasman and Yildirim (2006) as well as Grigorian and Manole (2006) paying more attention to comparative assessment of efficiency and identification of its determinants in a panel of transition or CEE countries. Beginning with Grigorian and Manole (2006) the methodology of articles on the main path was DEA or DEA-based. Interestingly, there was a gap of seven years until Pančurová and Lýocsa (2013), who are the last study on the main path that explored banking efficiency for a broad cross-section of countries in order to establish drivers of efficiency. With Pančurová and Lýocsa (2013), the main path was started to be led by Czecho-Slovak authors. Palečková (2017) investigated chiefly the effect of financial conglomeration on banking efficiency for a small panel of Visegrád Group countries, but studied also productivity change. Focused only on Slovak commercial banks, productivity change is the leitmotif of Boďa (2019), but Boďa and Piklová (2021) investigated the effect of diverse input-output specifications on efficiency scores. It should also be noted that the main path displayed in Fig. 3 constructed with global search with four main key routes is fairly robust to a change in parameters, and resembles the main paths produced by standard global search or forward local search.

The identified main path sheds light upon the prevailing research agenda and timeline in efficiency research of Czech and Slovak banks. First, between 2002 and 2005, the central topic was the effect of transition reforms and ownership upon banking efficiency. In the sparse period from 2006 to 2013, the research question was to find general factors

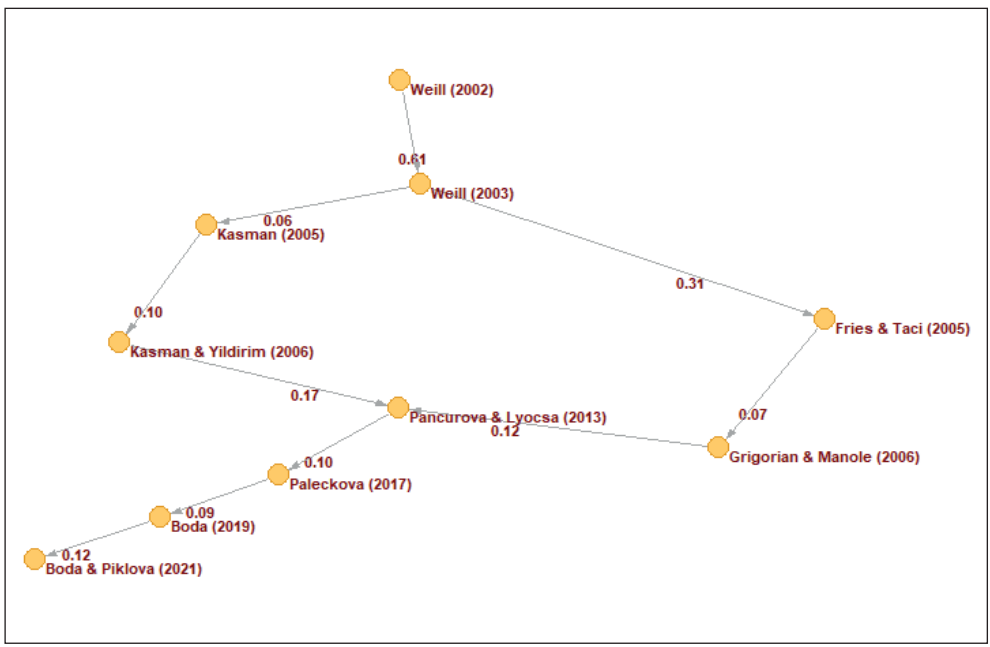

Fig. 3: Global main path

Note: The SPC (search path count) algorithm is used to determine traversal counts, and the graph reflects citation weights in the network. Main key routes are shown.

Source: own

of efficiency and in this period DEA became a leading methodology for efficiency exploration. Since 2013, the main say in efficiency research has been assumed by domestic authors with diversified topics of research including DEA-based productivity change.

Conclusions and insights

With a view of sketching historical trajectories and identifying the state of the art, this paper reviewed 44 journal articles listed in the Web of Science™ database whose substantial application focus was efficiency research of Czech and Slovak banks by frontier techniques. The reviewed items ranged from the pioneering study by Weill (2002) to the article by Moudud-Ul-Huq et al. (2022). Albeit this review is predated by Banerjee (2012), this paper is not just an update or a mere continuation of this prior review.

By dint of standard tools of science mapping, the paper sought to reveal the intellectual structure of efficiency research in Czecho-Slovak banking, and to describe the evolutionary development of its research agenda. Whereas the choice of the countries might have been more liberal and possibly include the other two Visegrád Group countries, this might not be desirable since Czech and Slovak banking provide a unique case study of banking sectors that came to existence after a rarely peaceful dismemberment of a multinational federation, here with a Socialist past, and that both soon became involved in the project of European integration. Furthermore, there is an aspect of comparability since there are only small differences in the legislative framework of both countries, and large Czech and Slovak banks commercial banks are operated by the same banking groups and run under similar, if not identical, principles. Both transition issues and manifold aspects of operations were represented in the research agenda and transformed into distinct research waves.

The first identifiable wave of research was represented by foreign authors who examined issues of economic transition and its impact on performance of banks. The first generation of authors such as L. Weill, A. Kasman, P. Wachtel, J. P. Bonin, I. Hasan, A. Taci and S. Fries typically contributed literally by a few published studies that have been heavily cited and are comparative in nature. The central topics of these first studies were effects of privatization, foreign ownership and complementarily also those of bank size upon efficiency. This wave of research endured until about 2013 when the baton passed into the hands of authors of Czecho-Slovak provenience. The lesson of transition research is the stylized fact that foreign ownership is generally beneficial to efficiency and that bank size is an advantage that bigger banks may typically exploit to outperform smaller banks at least in some form of efficiency. Historically, with the accession of the Czech and Slovak Republics to the European Union, most Czech and Slovak banks were already financed by foreign capital that had assumed strategic influence, which is the apparent reason why productivity change studies could conclude safely an improvement of banking productivity in the two decades following the transition in the mid-1990s. Hence, efficiency-based productivity change research is another coherent research front that occupied Czecho-Slovak authors such as I. Palečková, K. Kočišová, M. Boďa, E. Zimková intensively between 2017 and 2019. Whilst the studies varied in the attribution of banking productivity dynamics to driving factors of change, they agreed in outlining rise in productivity of both Czech and Slovak banks. Meanwhile, in addition to these two most prominent topics, there were secondary streams that attracted more or less repetitive research interest such as the relation between bank efficiency and failure (which was an ad hoc topic culminating in 2008), the effect of efficiency on bank competition, the effects of European integration or the Global Financial Crisis on efficiency. For instance, European Union membership and euro adoption were generally assessed as positive and the Global Financial Crisis was unanimously found to exert detrimental effects in spite of strong resilience of banks.

The historical development of research interests suggests some research gaps implied by an otherwise suddenly discontinued research agenda. Whereas the transition impact upon Czech and Slovak banks was assessed on several occasions, it is not clear whether long decades after the transition the Czech and Slovak banking sectors are now comparable in efficiency with developed (bank-based) banking sector that did not have to sustain a painstaking transition. There are still unresolved issues of the relationship between banking efficiency and competition almost two decades after the Global Financial Crisis or the impact of the COVID-19 pandemic upon banking productivity.

Admittedly, Czech and Slovak conditions alone are not normally in the forefront of global banking efficiency research except when it comes to conducting an extensive comparative study, so the field upon which the present survey centres is partly bound to develop in isolation. Nonetheless, the co-citation analysis confirmed that efficiency research of Czech and Slovak banks grew out of the canonical works of frontier efficiency research and is an integral part of global banking efficiency research. Furthermore, productivity patterns evaluated through the lens of Lotka's law do not divorce Czecho-Slovak banking efficiency research from its global counterpart. Yet, this is not to say that authors focusing on Czech and Slovak banks are not struggling to publish their output in journals with a wider reach. On the contrary, typical outlets of these authors are journals maintained by academic institutions in CEE countries. The most prominent journals published results of this research field in the first decade of the past 20 years when the transition-related topics culminated. The repetitive authors with at least 2 published articles can be roughly sorted into two generations. The first generation laid foundations in the first decade, say between 2002 and 2012, and is represented by 10 economists, namely L. Weill, J. P. Bonin, P. Wachtel, I. Hasan, A. Kasman, D. Stavárek, J. Lešanovská, J. Podpiera, A. Pruteanu-Podpiera, and A. M. Andrieș. The second generation was active in the second decade, starting after about 2012, and is represented by 7 authors, K. Kočišová, M. Boďa, E. Zimková, I. Palečková. All these are of Czech or Slovak provenience. Whereas the first generation of scholars would set research trends in the first decade, the second generation prescribes the research interests now, and it is where a new researcher should stop to acquaint oneself with the state of the art.

An obvious limitation of the present survey is that it only sources journal articles listed in Web of Science™ and ignores Scopus®, which necessarily implies skipping relevant studies in the field. That being said, there are guidelines on merging searches from both databases for the purpose of a bibliometric analysis (e.g., Echchakoui, 2020).

The following 44 articles were incorporated in the survey and are listed fully with bibliographic details amongst the references: Andrieș (2011), Andrieș and Cocriș (2010), Azorfa et al. (2013), Balcerzak et al. (2017), Baruník and Soták (2010), Belás et al. (2019), Boďa (2018), Boďa (2019), Boďa and Piklová (2021), Boďa and Zimková (2015), Boďa and Zimková (2017), Boďa and Zimková (2019), Bonin et al. (2005a), Bonin et al. (2005b), Černohorská et al. (2017), Čupić and Širaňová (2018), Dráb and Kočišová (2018), Fries and Taci (2005), Grigorian and Manole (2006), Havránek et al. (2016), Kasman (2005), Kasman and Yildrim (2006), Kočišová (2012), Kočišová (2014a), Kočišová (2014b), Kočišová (2015), Kočišová and Šugerek (2021), Lešanovská and Weill (2016), Matoušek et al. (2015), Moudud-Ul-Huq et al. (2022), Palečková (2017), Palečková (2019), Pančurová and Lýocsa (2013), Poghosyan and Poghosyan (2010), Pruteanu-Podpiera and Podpiera (2008), Podpiera and Weill (2008), Pruteanu-Podpiera et al. (2008) Stavárek (2005a), Stavárek (2006), Svitálková (2014), Weill (2002), Weill (2003), Weill (2006), Weill (2007).

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The impact of Fintech on bank development: A meta-analysis investigation

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Abstract: *To test whether the results of the empirical literature on bank Fintech are affected by the characteristics of specific research, the paper selects existing high-quality empirical literature to conduct a meta-analysis. It finds that the empirical estimation results conducted across various studies are influenced significantly by factors such as sample interval, estimation methods, measurement indicators for Fintech and bank development, and the inverse of the model count. Specifically, the probability of obtaining significant estimation findings increases with earlier sample start-time and the use of risk or Fintech index data; however, the inverse is true for more models adopted, or the use of dynamic panel estimation methods. Meanwhile, the probability of obtaining significant positive estimation findings increases with the wider sample coverage. Furthermore, estimating methods, and measurement indices for Fintech or bank's risk, all significantly contribute to the significant negative estimation results. Moreover, the funnel plot asymmetry analysis reveals the existence of publication biases in the sample research; the greater the significance of the empirical estimation results, the higher the probability of publication for the article. Therefore, it is vital to consider the heterogeneity and possible publishing biases among the extant empirical research when examining the impact of Fintech on bank development.*

Keywords: *Fintech, bank development, meta-analysis, meta-regression.*

JEL Classification: *G21, O16, O33, C99.*

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Introduction

Throughout the years, a substantial body of literature has developed around bank Fintech. Nevertheless, a consensus on the relationship between Fintech and various aspects of bank development, such as financial performance, management efficiency, and stability, has yet to be reached. With the potential for Fintech to revolutionize financial services and enable banks to leverage economies of scale and scope (Schindler, 2017), it is generally accepted that Fintech has a positive impact on bank development (Kayed et al., 2024). However, with the introduction of financial stability from Fintech (Financial Stability Board, 2017), the associated risks are increasingly acknowledged. Some research suggests that there may also be a negative effect on Fintech-related

banking (Geng et al., 2023). This indicates that the impact of Fintech on bank development remains a topic of debate, as research results may differ based on variations in sample size, sample selection period, modeling approaches, and control variables. Given the importance of banks in the financial system, it is critical to combine the relationship between Fintech and bank development.

Currently, there is a limited amount of literature examining bank Fintech, yet no specific review articles focus on Fintech's impact effect. A few review papers have addressed the opportunities, challenges, and development trends related to bank Fintech (Murinde et al., 2022; Pandey, 2024), yet they do not provide a comprehensive overview of the research in this area. Additionally, several review studies have examined the relationship between artificial intelligence, machine learning, or blockchain, and bank development (Patel et al., 2022; Sadok et al., 2022); however, these studies tend to focus on specific aspects of Fintech rather than adequately considering its impact effect.

The disagreement over the impact of Fintech on bank development serves as the primary driving force behind this paper. The paper aims to investigate the impact effect of Fintech on bank development by using the meta-analysis method. It is a literature review method that synthesizes and re-estimates existing empirical research (Weichselbaumer & Winter-Ebmer, 2005). As a quantitative empirical research technique, meta-analysis leverages the heterogeneity found in regression models from the selected literature as independent variables, with the estimation results acting as the dependent variable in a multiple regression analysis. This methodology effectively highlights variations in empirical outcomes linked to differences in statistical methods, deviation of model error, and research datasets, quantifying how these factors contribute to inconsistencies in research findings (Bel & Fageda, 2009; Stanley & Jarrell, 2005a). Moreover, this method helps identify potential publication biases that could occur during the dissemination process, improving the reliability of empirical results and avoiding theoretical limitations.

The paper makes two significant contributions to the existing literature. First, it is the inaugural article to perform a meta-analysis in the realm of bank Fintech, thereby expanding and enriching the current body of knowledge on the topic. Second, it theoretically examines the effects of Fintech on bank development and carries out an empirical analysis to identify factors that may result in varying impact effects. These insights will assist countries in devising and executing policies related to bank Fintech.

The remainder of this paper is organized as follows. Section 1 reviews the established bank Fintech literature from a theoretical and practical perspective. Section 2 illustrates the data collection, coding, and model design required by the meta-analysis approach. The findings of the meta-analysis and the publication bias discussion are presented in Section 3. The conclusion forms the final portion.

1. Theoretical background

1.1 Opportunity and challenge for bank Fintech

Financial technology, or Fintech, as defined by the National Economic Council (2017), refers to encompassing a wide spectrum of technological innovations that impact a broad range of financial activities, including payments, investment management, capital raising, deposits and lending, insurance, regulatory compliance, and other activities in the financial services space. The significance of Fintech lies in its ability to make financial services more accessible, efficient, and user-friendly. The banking industry, being a significant part of the financial sector, has been at the forefront of embracing these technological advancements (Schindler, 2017). Credit cards, debit cards, and cash dispensing devices like automated teller machines (ATMs) have been gradually introduced in banks since the 1960s. Then, as telephones and information technology gained popularity in the 1970s and 1980s, the impact of information technology on bank development was evident in the changes made to certain backend systems as well as financial products and services (McKendrick, 1992). At the turn of the millennium, the IT boom established a rational foundation for the banking sector (Gangopadhyay et al., 2022). The evolution of electronic banking continued to strengthen the impact of information technology on bank development, primarily manifested in the organizational structures of banks (Onay & Ozsoz, 2013). Following the 2008 financial crisis, emerging financial technologies, such as artificial intelligence, blockchain, cloud computing, big data, and the internet of things, have overturned

the traditional banking business model and forced banks to upgrade and transform to meet the demands of customers (Financial Stability Board, 2017). Fintech drives banks to go digital and transform towards more customer-centric (Jünger & Mietzner, 2020) and its applications in the banking sector continue to expand.

However, the bank faces issues of both increased risk and degraded stability, in addition to the opportunity to fully exploit economies of size and scope brought about by Fintech (Marinč, 2013). On one hand, emerging Fintech platforms are not only entering markets that conventional banks might not service well, but they are also upending the established methods of financial intermediation (Cai, 2018; Jagtiani & Lemieux, 2018). Furthermore, this unfavorable sentiment would increase if Fintech advances were limited to non-financial startups (Chen et al., 2019). For this reason, rumors occasionally circulate that Fintech platforms may eventually replace bank credit in certain areas or nations (Hodula, 2022). Conversely, when Fintech is applied unregulated to the banking industry, it has grown to be a force that threatens the stability of banks (Macchiavello, 2018). Accordingly, authorities worldwide are now paying attention to the supervisory and regulatory challenges brought up by Fintech (Financial Stability Board, 2017).

1.2 Empirical evidence and dispute for bank Fintech

While debates persist regarding bank Fintech, there is a general consensus that Fintech advances bank growth. Is this consensus supported by empirical evidence? Some scholars have carried out pertinent empirical research in an attempt to provide an answer to this focus. In this section, we examine the following two key issues: (1) Do the findings of existing empirical research support the mainstream proposition? (2) What particular features of the research do these empirical studies have?

We conducted a literature search using the Web of Science database, employing keywords such as Fintech, Internet information technology (IT), communication technology, digital, artificial intelligence (AI), blockchain, cloud computing, big data, internet of things, machine learning, data mining, and other related terms. Subsequently, we filtered the articles according to the following criteria: (1) The inclusion of one or more empirical models examining the relationship between Fintech and bank development. (2) Publication in a high-impact journal, as indicated by a high SCImago Journal Rank (SJR), and classified within Q1 or Q2, with Q1 representing the highest tier of journal influence. In conclusion, we have 43 empirical studies that highlight the relationship between Fintech and bank development. Tab. 1 illustrates how this topic has been expanding rapidly since 2017, with the majority of studies published in 2023 and 2024. This is due to three factors: (1) A consensus on the definition of Fintech as technology-enabled innovation in financial services that may lead to new business models, applications, processes, or products with a material impact on the provision of financial services; (2) The emergence of bank Fintech as a hot topic due to accumulated financial risks and financial disintermediation that accompany the rapid development of Fintech; and (3) The accumulation of data from Fintech's development, offering the opportunity for scholars to carry out empirical research.

Tab. 1: List of 43 empirical studies of bank Fintech – Part 1

Date	Author	Sample period	Estimation method	Region
2007	**Beccalli**	1995–2000	Ordinary least square method	France and other 4 European
2013	**Onay and Ozsoz**	1990–2008	Fixed effect	Turkey
2017	**Filip et al.**	2007–2013	Random effect	Poland
2017	**Mocetti et al.**	2006–2016	Fixed effect	Italy
2018	**Qiao et al.**	2010–2015	GMM	China
2020	**Carbó-Valverde et al.**	2016	Fixed effect	Spanish
2020	**Chen et al.**	2011–2016	Random effect	China

Tab. 1: List of 43 empirical studies of bank Fintech – Part 2

Date	Author	Sample period	Estimation method	Region
2020	**Cheng and Qu**	2008–2017	Fixed effect	China
2020	**Forcadell et al.**	2003–2016	GLS	Australia and other 13 developed countries
2020	**Phan et al.**	1998–2017	GMM	Indonesia
2021	**Lee et al.**	2003–2017	GMM	China
2021	**Sheng**	2011–2018	Random effect	China
2021	**Wang et al.**	2011–2018	Random effect	China
2021	**Yao and Song**	2011–2019	GMM	China
2022	**Banna et al.**	2011–2018	Random effect	Angola and other 29 African countries
2022	**Cao et al.**	2011–2018	Fixed effect	China
2022	**Cheng et al.**	2008–2019	Fixed effect	China
2022	**Pierri and Timmer**	2007–2010	Fixed effect	US
2022	**Zhao et al.**	2003–2018	GMM	China
2023	**Fang et al.**	2007–2021	Fixed effect	China
2023	**Geng et al.**	2008–2018	Fixed effect	China
2023	**Guo and Zhang**	2008–2019	Fixed effect	China
2023	**Hao et al.**	2011–2020	Fixed effect	China
2023	**Khan et al.**	2010–2022	GMM	Saudi Arabia
2023	**Nguyen-Thi-Huong et al.**	2015–2021	GMM	Vietnam
2023	**Wang et al.**	2005–2022	Fixed effect	China
2023	**Wang et al.**	2014–2019	Fixed effect	China
2023	**Wu et al.**	2011–2019	Fixed effect	China
2023	**Wu et al.**	2007–2019	GMM	China
2023	**Zhang et al.**	2013–2021	GMM	China
2023	**Zhao et al.**	2013–2020	GMM	China
2024	**Chen and Shen**	2011–2018	GMM	China
2024	**Hu et al.**	2011–2020	Fixed effect	China
2024	**Karim and Lucey**	2013–2021	Fixed effect	Malaysia
2024	**Ren et al.**	2014–2020	Fixed effect	China
2024	**Safiullah and Paramati**	2003–2018	GMM	Australia
2024	**Tang et al.**	2011–2021	Fixed effect	New Zealand
2024	**Wang et al.**	2011–2019	Fixed effect	China
2024	**Wu et al.**	2008–2022	Fixed effect	China
2024	**Xu and Yang**	2011–2019	Fixed effect	China

Tab. 1: List of 43 empirical studies of bank Fintech – Part 3

Date	Author	Sample period	Estimation method	Region
2024	**Yu**	2005–2020	GMM	China
2024	**Zhao et al.**	2010–2021	GMM	China
2024	**Zhu and Guo**	2016–2019	Fixed effect	China

Source: own

The initial phase of conducting an empirical study on bank Fintech is to determine how to measure the level of Fintech. There are three ways to gauge the degree of Fintech, per the empirical literature currently in publication (Tab. 2). The first method is the Fintech index, which consists primarily of two data sources. To construct the complete index, one must employ principal component methods (PCA) after identifying frequently searched keywords on Baidu, a major search engine in China, or within a bank's annual report. These terms are relevant to bank Fintech and typically consist of five words or more. Subsequently, PCA is applied to integrate these into a singular, encompassing index (Yao & Song, 2021). Another metric is the Internet finance development index, which is devised and disseminated by academic institutions and contains data at three levels: national, prefectural city, and county (Hu et al., 2024; Sheng, 2021). A second approach to measuring the extent of bank Fintech is through the ratio of information technology expenditures to all non-interest expenses. This information can be found directly in the annual report of the bank (Beccalli, 2007; Carbó-Valverde et al., 2020). Simultaneously, some researchers incorporate data from non-bank sources that are closely related to Fintech, such as P2P trading volume and the total number of Fintech companies established (Chen et al., 2017; Lee et al., 2021). The third method of quantification employs a dummy variable that is assigned a value of 1 or 0 based on whether the bank engages in Fintech activities (Zhang et al., 2022).

Beyond the dependent variable, another primary concern is the selection of methodologies for measuring bank development. Three methods have been employed to measure bank development in previous studies. The first is the financial index, which is a representation of the bank's financial condition. These indices include metrics such as return on asset (ROA), return on equity (ROE), net interest margin (NIM), liquidity ratio, and growth rate of deposits, among others (Chen et al., 2020; Karim & Lucey, 2024). A second method is the efficiency index which takes into account profit, cost, and management efficiency (Ren et al., 2024; Zhao et al., 2022). These factors are pertinent to the impact of Fintech on bank development. The third is the risk index, which quantifies the risk of banks by incorporating

Tab. 2: Measurements method for the level of Fintech in the existing literature

Indicator types		Calculation formula
Fintech index	Composite index	Synthesized by using the methods of the methods of principal component analysis and factor analysis
	Internet finance development index	Designed and published by academic institutions
Information technology expense ratio		Information technology expenses to non-interest expenses
Dummy variable		The value would be 1 if the bank has related Fintech activities

Source: own

metrics such as the *Z*-score (Banna et al., 2022; Safiullah & Paramati, 2024), the non-performing loan ratio (NPL) (Zhao et al., 2023), and additional risk indicators.

In the domain of model specification, there exists a significant debate on the definition of Fintech's contribution to bank development. A consensus among many scholars holds that Fintech has a linear impact on banks' development (Cheng et al., 2022; Wu et al., 2023). However, some researchers suggest that Fintech's impact is u-shaped rather than linear (Wang et al., 2021). Additionally, it is still uncertain if the lag of the proxy variable representing bank development should be included in the model (Zhao et al., 2023). Meanwhile, as everyone knows, the models can only function properly at some point in time if the cumulative impact of the bank development is taken into account (Qiao et al., 2018). As a result, the statistical techniques employed in the current scholarly literature vary as well. As Tab. 1 illustrates, the majority of the literature uses the ordinary least square (OLS) method, along with fixed effect (FE) and random effect (RE) methodologies, to estimate the impact of Fintech on bank development. Yet, the estimation results are unable to capture the true impact size of Fintech on bank development because of endogenous issues brought on by measurement errors, two-way causation, and missing factors. To more precisely determine the relationship between Fintech and bank development, certain researchers estimate the model using the generalized moment methods (GMM) and instrument variable (IV) techniques (Phan et al., 2020; Safiullah & Paramati, 2024). And what variables fall under the category of tool variables? The lag of the independent variable, internet penetration ratio, and the average income level of the city where the bank's R&D facilities are located have been identified as potential candidates (Cheng & Qu, 2020; Hu et al., 2024; Mocetti et al., 2017). However, the ability of these macro and meso-level instrumental variables to address endogeneity remains a contentious issue. The optimal selection of instrumental variables and the identification of the most appropriate instruments continue to be subjects of scholarly debate.

Moreover, variations in data structures, sampling intervals, and geographic regions likely contribute to the observed heterogeneity in empirical findings. In addition to getting more precise dynamic information and minimizing multicollinearity, panel data are conducted in practically all of the current literature. Tab. 1 displays an overview of the sampled literature, comprising 1 cross-sectional dataset, 14 dynamic panel datasets, and 28 static panel datasets. Apart from this, it demonstrates that sampled banks are spread across more than 50 countries from 1990 and 2022, with sample periods ranging from 1 to 20 years. It is also evident that the majority of studies concentrate on bank Fintech in China, given that 29 articles are authored by Chinese scholars. These variations may lead to the heterogeneity observed in the empirical estimation results across the articles.

Is there a consensus within the existing literature regarding the bank Fintech impact effect? This study aggregates empirical findings based on the classification of proxy variables for bank development and Fintech. As is shown in Tab. 3, the following observations are made: (1) The majority of models utilize financial indicators as proxies for bank development. The selection of 134 financial and 63 non-financial variables as proxies indicates a preference for financial variables among scholars because bank financial data is readily available in annual reports. (2) Identifying a suitable proxy to reflect the Fintech level remains challenging. Tab. 3 shows that 110 models incorporate the Fintech index, while 43 models use the IT expense ratio. Although a majority of the models include a dummy variable, it is widely recognized that such variables cannot precisely capture the true Fintech level of a bank; they merely indicate the presence or absence of financial technology in commercial banks. (3) Empirical findings regarding the impact of Fintech on bank development are inconclusive. With 37 studies showing non-significant results, and 102 and 58 studies reporting positive and negative effects, respectively, it implies that the current empirical findings are heterogeneous and potentially influenced by various factors.

Based on the aforementioned, it is clear that the specifics of each study influence the effects of Fintech on bank development, making it challenging for us to reach a generally consistent conclusion. Nevertheless, identifying the specific factors within these studies that sway the empirical results is crucial. To this end, a comprehensive meta-analysis of the existing literature is warranted.

Tab. 3: **Statistics of empirical results on the relationship between Fintech and bank development**

Indicators		Positive	Negative	Non-significant	Total
Dependent variables	Financial variables	66	43	25	134
	Non-financial variables	36	15	12	63
	Subtotal	102	58	37	197
Independent variables	Index variables	55	47	8	110
	IT expense ratio	17	14	12	43
	Non-index variable	14	13	17	44

Note: When negative indicators for bank development, such as "bank risk," etc., are documented, the data in the "positive" and "negative" columns are presented in reverse order.

Source: own

2. Research methodology

2.1 Data

Meta-analysis has evolved since the 1990s into the most sophisticated technique for literature retrospective analysis in the social sciences, humanities, and natural sciences. The data were gathered following the procedures shown in Fig. 1.

Initially, we identified keywords that would help us focus on publications related to the intersection of the bank and Fintech. Considering both traditional and cutting-edge financial technologies, we utilized the following search string: TI = (bank AND (Fintech OR financial technology OR IT OR information technology OR internet OR phone OR mobile OR AI OR artificial intelligence OR blockchain OR cloud computing OR data OR digital))

We conducted our search in the reputable economic databases of the Web of Science and initially identified 18,043 potential studies. To ensure the quality and relevance of the studies, we limited our scope to journal articles published in economic journals ranked Q1 or Q2 by the SJR index. After the exclusion

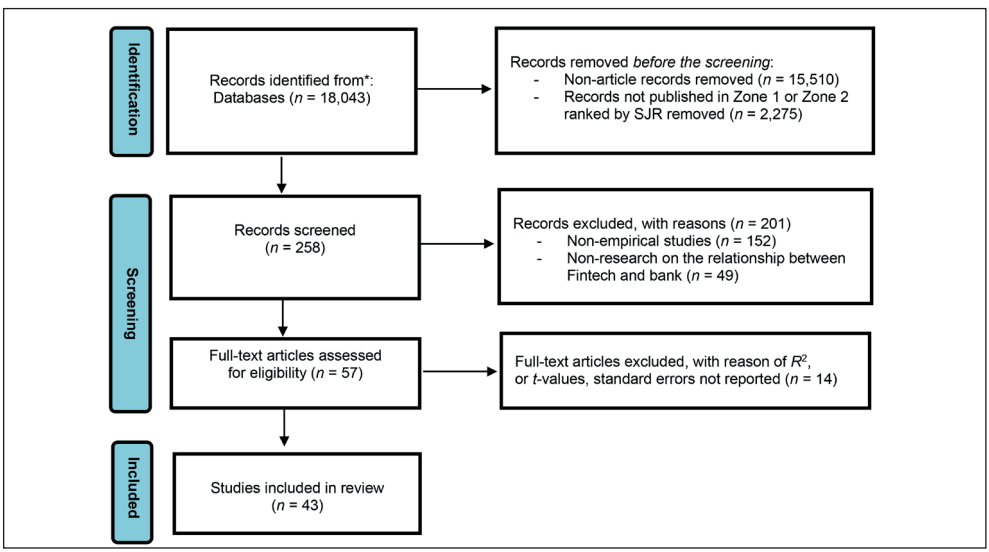

Fig. 1: **Fintech literature search flow diagram**

Source: own

of the non-empirical studies and those not directly examining the relationship between Fintech and banking, we were left with 57 articles for full-text review.

Our selection criteria for the empirical articles were stringent: the articles had to provide a detailed report of empirical results, particularly the correlation coefficients between variables, and the sample characteristics. Where possible, the articles should also include estimated coefficients for independent variables, *t*-values, standard errors, or other statistical values that can be converted into correlation coefficients. Through this rigorous exclusion process, we finally included 43 empirical studies in our meta-regression analysis, as detailed in Tab. 1.

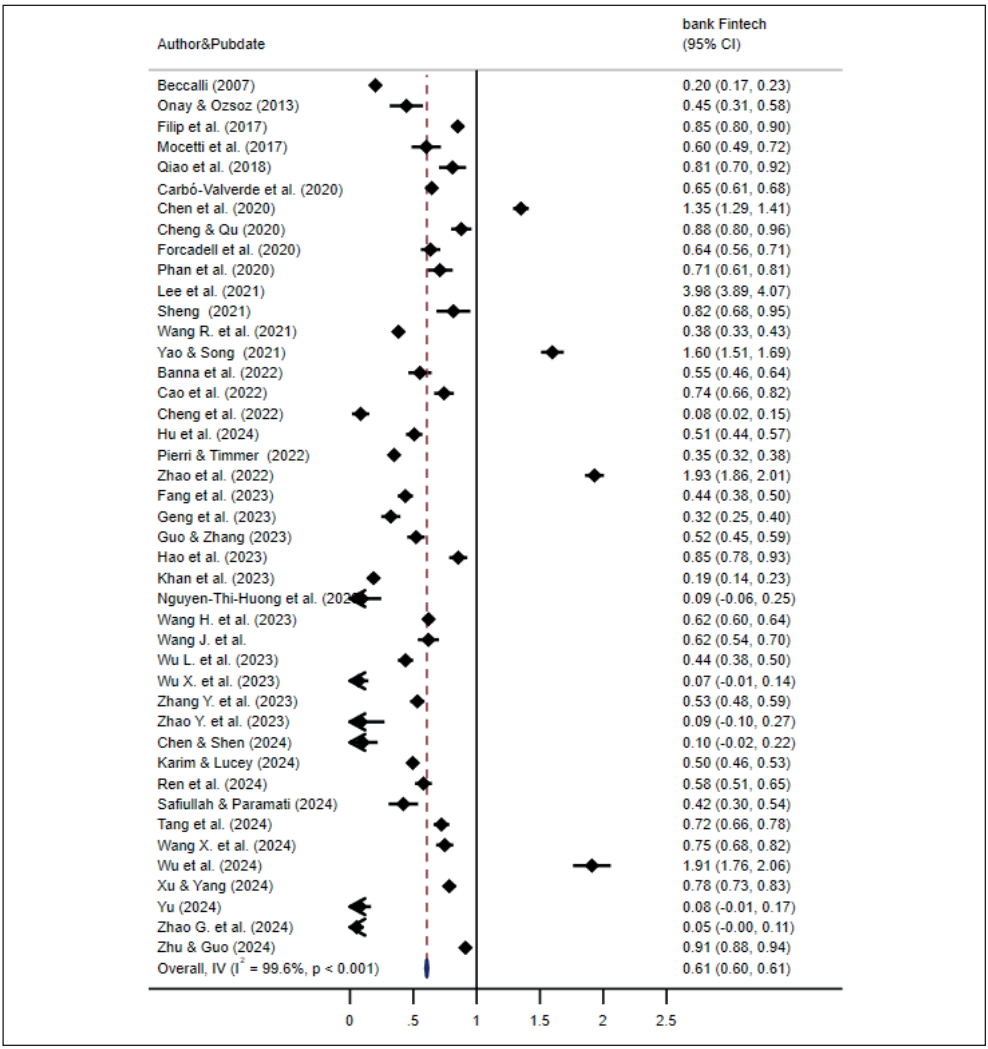

Fig. 2: Forest plot of the existing empirical studies on bank Fintech

Note: The first effect size in each article is shown by the diamond plot, which is converted using the Fisher *Z* method.

Source: own

The majority of the chosen empirical studies have been published since 2017, with the sample bank data encompassing 33 years from 1990 to 2022. The sample includes banks from both developing and economically advanced countries, including China, the European Union, the United Kingdom, Australia, and several countries in Africa. In the meantime, the literature addresses a broad spectrum of topics related to Fintech, including its impact on bank efficiency, risk, and financial performance, among numerous other areas.

As shown in Fig. 2, the diamond shapes representing the effect sizes of the individual studies do not cross the null effect line (a vertical line at the scale of 1), indicating that the calculated effect sizes of the studies are statistically significant. The overall effect size is 0.61, which is greater than 0.5 but less than 1 (Stanley & Jarrell, 1998), suggesting that Fintech significantly impacts the development of banks. The I-squared result is significantly greater than 50%, indicating heterogeneity in the impact of Fintech on bank development across the studied, suggesting that the influence of Fintech on bank development may vary depending on the characteristics of the selected samples.

2.2 Variables

The paper employs meta-analysis to evaluate whether the empirical estimation results reported in the existing literature are influenced by specific research characteristics. Consequently, choosing the right variables is essential. Three variables – *significance, positive significance* (labeled as "*Positive*"), and *negative significance* (labeled as "*Negative*") – are selected as the dependent variables per the goal of the study. The values of these variables are ascertained through the application of *t*-statistics to assess the significant relationships among the variables in the empirical studies (Stanley & Jarrell, 2005). The *significance* value is 1 when Fintech significantly influences bank development; otherwise, it is coded as 0. The value of *Positive* is 1 when Fintech has a significant positive impact on bank development; otherwise, it is coded as 0. The degree of *Negative* is 1 when Fintech hinders a bank's growth; otherwise, it is coded as 0.

We selected the *sample observations* (*Observations*), *start year* (*Start*), *end year* (*End*), *region* (*Region*), and estimation *method* (*Method*) based on the general guideline for selecting moderator variables that capture the fundamental features of the empirical literature. The last two variables, *Region* and *Method*, are considered fictitious. The value of the *Region* is coded as 1 if the sample bank is restricted to a single nation; otherwise, it is coded as 0. Moreover, the *Method*'s value is coded as 1 when the model employs a dynamic panel estimation approach; otherwise, it is coded as 0.

Concurrently, we employ six dummy variables, one for each, to capture the features of Fintech and bank development. *EffDev*, *RiskDev*, and *FinDev* are the three dummy variables used to reflect the development characteristics of banks across the studies. Additionally, we characterize Fintech features within each study using three dummy variables: *FintechIndex*, *IT*, and *Dummyindex*. The matching value is coded as 1 if any indicator is used in the individual study; otherwise, it is coded as 0.

Furthermore, to correct for potential biases arising from the extraction of multiple data sets from a single article, we employ the *Weight* variable followed by Weichselbaumer and Winter-Ebmer (2005), which is defined as the inverse of the number of models estimated within each study.

All of the variable information as well as the descriptive statistics for the sample data are shown in Tab. 4.

Tab. 4: Variables description for meta-regression analysis – Part 1

Variable	Description	Obs.	Mean	Std. dev.	Min	Max
Significance	Dummy variable. When Fintech has a significant effect on bank development, the value is 1, otherwise it is 0.	197	0.802	0.399	0	1
Positive	Dummy variable. When Fintech has a significantly positive effect on bank development, the value is 1, otherwise it is 0.	197	0.437	0.497	0	1

Tab. 4: Variables description for meta-regression analysis – Part 2

Variable	Description	Obs.	Mean	Std. dev.	Min	Max
Negative	Dummy variable. When Fintech has a significantly negative effect on bank development, the value is 1, otherwise it is 0.	197	0.376	0.486	0	1
Observations	Number of the observations	197	1,449.218	1,750.019	114	7,619
Start	Start year of the sample data	197	2,005.376	7.764	1,990	2,016
End	End year of the sample data	197	2,015.838	6.343	2,000	2,022
Region	Dummy variable. When the sample bank is limited to one country, the value is 1, otherwise it is 0.	197	0.873	0.334	0	1
Method	Dummy variable. When the model adopts dynamic panel estimation method, the value is 1, otherwise it is 0.	197	0.203	0.403	0	1
FinDev	Dummy variable. When the model adopt financial variable representing bank development, the value is 1, otherwise it is 0.	197	0.350	0.478	0	1
EffDev	Dummy variable. When the model adopt efficient variable representing bank development, the value is 1, otherwise it is 0.	197	0.254	0.436	0	1
RiskDev	Dummy variable. When the model adopt risk variable representing bank development, the value is 1, otherwise it is 0.	197	0.330	0.471	0	1
FintechIndex	Dummy variable. When the model adopt Fintech index representing the level of Fintech, the value is 1, otherwise it is 0.	197	0.558	0.498	0	1
IT	Dummy variable. When the model adopt IT expense ratio representing the level of Fintech, the value is 1, otherwise it is 0.	197	0.218	0.414	0	1
DummyFin	Dummy variable. When the model dummy variable to represent whether the bank adopt financial technology, the value is 1, otherwise it is 0.	197	0.223	0.418	0	1
Weight	Reciprocal of the models number	197	0.484	0.343	0.08	1

Source: own

2.3 Model specification

We formulated the following three meta-regression equations following the meta-regression equation's general pattern.

$$ys_{ij} = \beta_0 + \sum_{k=1}^{K} \beta_k Z_{ijk} + \sigma_{ij} \quad (1)$$

$$yp_{ij} = \beta_0 + \sum_{k=1}^{K} \beta_k Z_{ijk} + \sigma_{ij} \quad (2)$$

$$yn_{ij} = \beta_0 + \sum_{k=1}^{K} \beta_k Z_{ijk} + \sigma_{ij} \quad (3)$$

where: i, j = 1, 2, ..., N; k = 1, 2, ..., K; ys_{ij}, yp_{ij} and yp_{ij} – the significant regression result, the positive significant regression result, and the negative significant regression result of the impact of Fintech on bank development in the j^{th} estimation of the i^{th} study, respectively; Z_{ijk} – a set of proxy variables that characterize the model design features leading to differences in empirical results, including *Observations*, *Start*, *End*, *Region*, *Method*, *FinDev*, *EffDev*, *RiskDev*, *FintechIndex*, *IT*, *DummyFin*, and *Weight*; β – the meta-regression coefficients to be estimated; σ – the random disturbance term in the meta-regression analysis.

Given that each of the dependent variables is dichotomous, we employ the probit model to conduct separate meta-regression estimates for the three aforementioned models.

3. Results and discussion

3.1 Results of meta-regression

We employed the probit method to conduct a meta-regression analysis on the three aforementioned models, with the dependent variables representing the significant effect, positive significant, and negative significant effects of Fintech on bank development. The estimation results are shown in columns (1–3) in Tab. 5.

As demonstrated in Tab. 5, column (1), the moderator variables *Start*, *Method*, *RiskDev*, *FintechIndex,* and *Weight* exhibit significant coefficients at varying significance levels ranging from 1% to 10%, indicating their significant impacts on the empirical findings to date. Among these, the greater probability of obtaining significant effects of Fintech on bank development is higher when the sample data begins earlier or when more model designs are considered. In addition, given that the coefficients are positive, including *RiskDev*, or the Fintech index to the model increases the probability of obtaining significant estimation findings; however, this probability is decreased when the dynamic panel model is used.

Tab. 5, column (2) displays the estimation findings, with the dependent variable being the positive significant effect of Fintech on bank development. The probability of receiving significant positive estimate results is reduced regardless of which Fintech indicator is included in the model. However, the coefficient for the *End* variable is positive and significant at the 5% level, suggesting that a greater sample size increases the probability of obtaining significant positive estimation findings.

Tab. 5, column (3) presents the estimation findings, with the dependent variable being the negative significant effect of Fintech on bank development. There are more factors influencing the probability of obtaining a significant negative impact of Fintech on bank development when comparing the results in columns (1–2). Firstly, notwithstanding the *Method* variable, the significantly positive coefficient of the *Start* demonstrates that advancing the sample start date substantially can greatly raise the probability of receiving negative significant regression results. Secondly, the *RiskDev* coefficient, which is positive and significant at the 5% level, indicates that there is a higher probability of receiving significant negative regression findings when utilizing the risk indicator for bank development. Thirdly, all variables indicative of the Fintech level exhibit significant coefficients, indicating that the type of Fintech indicators employed will influence the probability of receiving significant negative regression findings.

Based on these findings, it can be concluded that diverse study features significantly influence the empirical findings of Fintech on bank development, particularly the negative significant effect. Furthermore, it can be observed that the inclusion of different Fintech indicators in the model can have a significant impact on the empirical research's outcome.

Tab. 5: The meta-regression estimation for Fintech's effect on bank development – Part 1

	(1)	(2)	(3)
	Significance	**Positive**	**Negative**
Observations	−0.0000 (0.7140)	−0.0001 (0.1410)	0.0001 (0.1220)
Start	0.0776** (0.0240)	−0.0045 (0.8350)	0.0402* (0.0920)
End	−0.0079 (0.8550)	0.0705** (0.0380)	−0.0300 (0.3580)
Region	0.7190 (0.1680)	0.2460 (0.5650)	0.3210 (0.3420)
Method	−4.8900*** (0.0000)	0.2000 (0.5030)	−0.5940* (0.0660)

Tab. 5: The meta-regression estimation for Fintech's effect on bank development – Part 2

	(1)	(2)	(3)
	Significance	**Positive**	**Negative**
FinDev	0.8080 (0.1290)	0.0902 (0.8330)	0.9150 (0.2190)
EffDev	0.9170 (0.1630)	0.2780 (0.5750)	0.8010 (0.3300)
RiskDev	1.2110** (0.0380)	−0.5750 (0.1950)	1.6680** (0.0250)
FintechIndex	4.6530*** (0.0000)	−5.4990*** (0.0000)	5.5970*** (0.0000)
IT	0.2050 (0.8070)	−4.9210*** (0.0000)	5.0660*** (0.0000)
DummyFin	−0.4970 (0.5250)	−5.6230*** (0.0000)	5.2920*** (0.0000)
Weight	1.2030* (0.0710)	0.1250 (0.7610)	0.4580 (0.3150)
_cons	−140.8000** (0.0120)	−127.8000** (0.0150)	−27.4900 (0.5570)
N	197	197	197
Pseudo R^2	0.3852	0.1098	0.1425

Note: *P*-values are reported in parentheses; ***, **, and * indicate significance at the 1, 5, and 10% levels, respectively.

Source: own

Consequently, this underscores the importance of focusing not only on getting comprehensive data but also on selecting appropriate variables for the model in the research of Fintech on bank development.

3.2 Publication bias discussion

The issue of publication bias is likely to occur throughout the meta-regression analysis process. This occurs because publications with significant empirical findings have a higher chance of being published (Stanley & Jarrell, 2005). Conversely, if the empirical result is not statistically significant, the researchers often deem it meaningless or unhelpful, leading to cessation or postponement. However, this issue can substantially undermine the reliability of the meta-regress results, especially when it comes to the effect size being drastically overstated. Thus, while performing meta-regression analysis, this problem should be verified using the funnel asymmetry test method (Stanley, 2008), with funnel plots and linear regression estimation being typical identification methods.

In a funnel plot, the abscissa represents the effect size, while the ordinate represents the standard error. It is possible to determine whether or not there is publication bias in the body of current research by examining the shapes of the scattered points in the chart. The symmetrical distribution of the effect points around the line of merged effects indicates the absence of publication bias; asymmetry suggests its presence. To normalize the effect sizes for funnel plot analysis in our meta-analysis, we initially applied Fisher's *Z* transformation to the collected correlation coefficients as detailed in Formula (4). This step primarily serves to normalize the effect size.

$$\text{Fisher } Z\,(R_i) = 0.5 * \log\left((1 + r_i)/(1 - r_i)\right) \quad (4)$$

where: r_i is the correlation coefficients of the i^{th} individual literature, R_i is the effect size of the i^{th} individual literature.

Subsequently, Fig. 3 depicts our constructed funnel plot, with the ordinate indicating the standard error and the abscissa representing the effect magnitude. It is discovered that:

(1) The most impact points of studies are primarily located on the left side of the effect merging line, not symmetrically distributed on both, and (2) certain effect points are dispersed outside of the funnel plot. The first observation indicates the presence of publication bias within the current body of research, while the second finding indicates heterogeneity.

To identify the contributing factors or effect pathways leading to publication bias, additional analysis using the linear regression approach is required. Following Stanley's (2008) research, we estimate Equation (5).

$$R_{ij} = \beta_0 + \beta_1(1/SE_{ij}) + \varepsilon_{ij} \quad (5)$$

where: i, j = 1, 2, ..., N; R_{ij} – the effect size in the j^{th} estimation of the i^{th} study; the term of $1/SE_{ij}$ denotes the precision, which is the inverse of the standard error; the intercept β_0 serves as an indicator of the presence of publication bias, with its sign indicating the direction of this bias; a significant deviation of β_0 from zero suggests the existence of publication bias (if not, it is inferred that there is no publication bias); the slope coefficient β_1 reflects the relationship between the effect size estimates and the precision of the studies; a significantly positive β_1 indicates that studies with more substantial empirical results are more likely to be published.

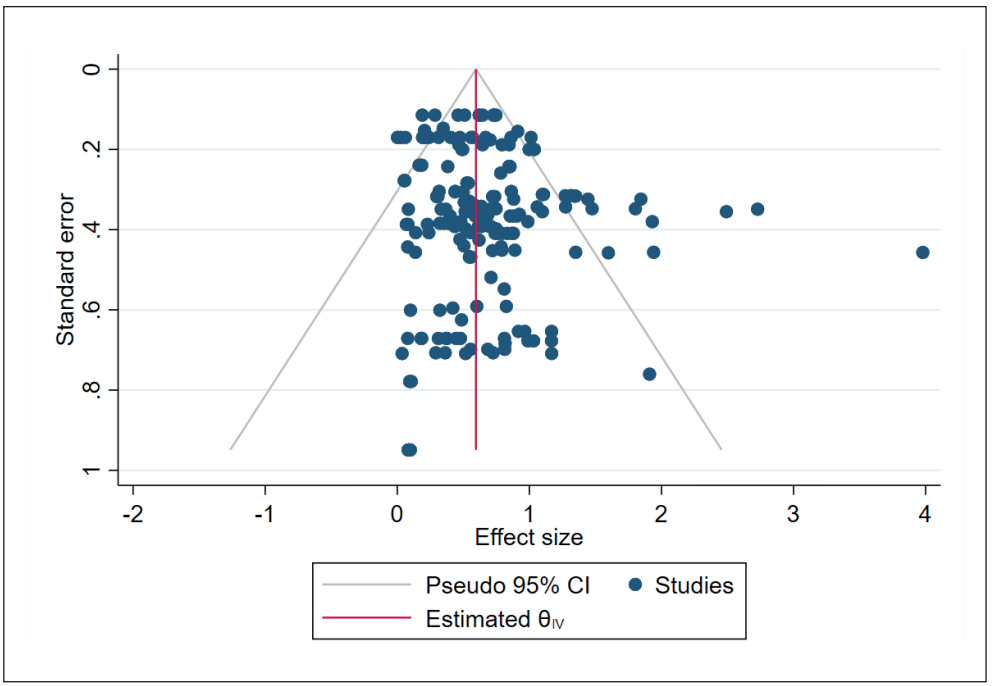

Fig. 3: Funnel plot with pseudo 95% confidence limits

Source: own

Appropriate grouping variables must be selected to achieve the research objective of assessing whether publication bias exists in the empirical studies. Three types of Fintech indicators used by the literature currently in publication serve as the appropriate grouping variable, as our research focus is on bank Fintech. Initially, we transform the effect size using Fisher's Z as the dependent variable, followed by the application of the ordinary least square method to estimate the formulas for each of the three groups. Tab. 6 presents the findings.

Tab. 6: Results by using OLS for the Funnel asymmetry test (dependent variable: effect size)

	(1)	(2)	(3)
	FintechIndex	***IT***	***DummyFin***
1/*SE*	−0.0095*** (0.0015)	0.0160*** (0.0012)	−0.0061*** (0.0013)
_cons	0.8760*** (0.0689)	−0.3160*** (0.0375)	0.4270*** (0.0606)
N	197	197	197
R^2	0.1240	0.5070	0.0730

Note: Standard errors are reported in parentheses; ***, **, and * indicate significance at the 1, 5, and 10% levels, respectively.

Source: own

It concludes that: (1) Evidence of publication bias is present in the extant empirical research, as the coefficients for the reciprocal of standard error in columns (1–3) are significantly different from zero at the 1% level. (2) The coefficients for the intercept term in columns (1–3) are significantly different from zero, suggesting that the existing research results display heterogeneity. (3) The *R*-squared values in columns (1–3), vary significantly and reflect the complexity of the relationships between the independent variables and the effect size; they also highlight the need for a nuanced understanding of the factors influencing the effect size in empirical research. (4) All things considered, given the small sample size, caution is advised when accepting these estimated results.

Conclusions

Both theoretically and practically, the research of Fintech on bank development is essential. As depicted in Tab. 3, 51.78% of the empirical results suggest that Fintech has a beneficial effect on bank development; however, the conclusions, when considered collectively, are not entirely consistent with these empirical findings. Consequently, this research conducts a meta-analysis and publication bias analysis to assess the robustness and potential biases in bank Fintech research, synthesizing and comparing data from 197 samples across 43 existing empirical studies.

It finds that the analysis of the impact of Fintech on bank development reveals a complex landscape in which current estimations are not only inconsistent across studies but are also deeply influenced by the intricacies of research design. The variability in findings can be attributed to several research characteristics, most notably the data structure, the analytical models, and the estimation methods. Furthermore, the impact of Fintech on bank development is not a one-dimensional phenomenon; instead, it is a multifaceted issue. This impact is particularly influenced by the intervals over which samples are drawn, the metrics used to assess bank development and Fintech's level, the estimation methods, and the number of models used. Additionally, the asymmetry observed in the funnel plot test indicates the presence of publication bias within the published literature. This necessitates a cautious interpretation of the existing empirical evidence and underscores the need for a more nuanced approach to understanding the relationship between Fintech and bank development. While our study offers insights into the impact of Fintech on bank development, it has two primary limitations. First, the analysis is constrained by the availability and quality of published research, which may not fully represent the breadth of ongoing exploration in this field. Second, our reliance on existing literature is subject to publication bias, potentially favoring studies with more significant findings.

Thus, future research should concentrate more on the following areas: (1) In-depth analysis of factors influencing the development of bank Fintech. This study reveals the heterogeneous impact of Fintech on banks, which is subject to a variety of influencing factors, including research characteristics such as, e.g., data

structure. Therefore, it is recommended that future research should delve deeper into identifying and summarizing the key factors influencing the development of bank Fintech, and thoroughly examine the individual and collective effects of Fintech on bank development, providing a solid empirical foundation for policy formulation. (2) Innovation in measurement methods for accurately assessing the impact of Fintech. In light of the diverse results that different estimation methods may yield in the relationship between Fintech and bank development, it is suggested that the academic and practical communities continue to innovate in methodology. This innovation will help establish a more robust theoretical framework, thereby providing precise and scientific evidence for the formulation of Fintech policies. (3) Promoting in-depth development of bank Fintech. More than half of the empirical studies indicate a positive impact of Fintech on bank development, highlighting the significant role Fintech plays in fostering bank growth. Consequently, it is recommended that banking institutions increase their investment in Fintech, and actively utilize Fintech to innovate in services, products, and organizational models, thereby comprehensively enhancing the financial performance and management efficiency of banks. (4) Strengthening the prevention and management of Fintech risks. The dual-edged nature of Fintech's impact suggests that while it can promote bank development, it may also introduce risks. Therefore, it is recommended that regulatory authorities intensify their oversight while encouraging commercial banks to leverage financial technologies to strengthen risk prevention capabilities, ensuring the stability and security of the financial system.

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Profitability determinants of cooperative Islamic insurance companies

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Abstract: *The aim of the paper is to investigate the profitability determinants of cooperative insurance companies in Saudi Arabia. The mentioned insurance companies conduct business activities on the largest Islamic insurance market in the world, which has a growing demand for insurance as an instrument of risk management and a meaningful potential for further growth. A particular motive for conducting this research was the fact that these companies have common characteristics with mutual insurance companies that represent one-third of the European insurance market. Taking into account the characteristics of cooperative insurance companies' business operations and the special structure of financial reports of these insurers relying on and in accordance with the results of the latest research on this topic as profitability determinants, we use return on assets (ROA), return on equity (ROE) and earnings per share (EPS), while explanatory variables include microeconomic (company size, investment profitability, investment income ratio, operator's fee, expense ratio, loss ratio, premium growth, risk exposure, capital adequacy, reinsurance dependence, specialization) and macroeconomic (interest rate and equity returns) variables. The data are collected on a quarterly basis for 28 companies from 2012 until the second quarter of 2020. We use first- and second-generation unit-root tests, heteroscedasticity test, cross-sectional dependence test, autocorrelation test, Hausman and Overid tests and multicollinearity test to determine model parameters. Due to the presence of heteroscedasticity and cross-sectional dependence, we analyze the data using Beck and Katz's panel corrected standard errors (PCSE) method. The results suggest that the financial performance of cooperative insurance companies in Saudi Arabia is determined by expense ratio, loss ratio, specialization (general or life and composite insurer) and the value of the operator's fee, which depends on the amount of the underwriting surplus. Taking into account the key characteristics of cooperative insurance companies, the results of our research can be used by decision makers of cooperative insurance companies in strategic and operational planning and can provide help for policymakers in other countries that use alternative insurance models.*

Keywords: *Panel data analysis, Saudi Arabia, Sharia compliant insurance, panel corrected standard errors, financial performance.*

JEL Classification: *G22, C33.*

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Introduction

Insurance companies in the 21st century operate in highly uncertain conditions permeated by economic crises, demographic changes, increasingly frequent catastrophic damages caused by natural disasters or human action; therefore, the financial results that, among others, reflect the management's ability to adapt to new conditions, but also the ability of insurance regulatory bodies to supervise insurance operations and ensure the stability of the insurance market, is subject of interest of numerous researchers. On the other hand, it should be emphasized that in addition to economic factors, the operations of insurance companies are influenced by social factors, including religion (Berry-Stölzle & Irlbeck, 2021; Berry-Stölzle & Xu, 2022). One of the areas that attracts the attention of researchers are companies that operate in accordance with the principles of Islamic Insurance, which are jointly often referred to as Takaful companies, although not all Islamic companies use the basic Takaful model. Unlike the commonly known models of insurance companies (such as joint stock companies or mutual insurers) that began to emerge in Europe in the 17th century, the first insurance company conducting business in accordance with Shari'ah principles was founded only in 1979 in Sudan (Pearson, 2021). Alshammari and Abdul-Wahab (2023) present a chronology of the development of Islamic insurance companies in 47 countries and highlight that, in 22 of these countries, Islamic insurance is not regulated by legal acts. Al-Amri and Hossain (2017) state that Islamic insurance has also developed in the United States and several European countries, with this form of insurance taking root most significantly in Great Britain. The development of Islamic insurance also impacts the reinsurance market. Reinsurance services that comply with Islamic financial principles, known as Retakaful, are also offered by two major Western companies – Swiss Re and Munich Re (through their licensed branches in the Middle and Far East).

Alam et al. (2023) conducted a bibliometric analysis of papers published on Islamic insurance from 1989 to 2022 in journals listed on Scopus. They found that the largest contribution to this topic comes from Malaysian publishers, while European and American publishers have also shown interest. Notably, a significant number of research papers were published in Great Britain during this period, which is not surprising given that Islamic insurance has taken root most significantly in that country. This underscores the relevance of researching companies that provide Shariah-compliant insurance services.

Based on the data presented in the Islamic Financial Services Board report (2023), it can be concluded that insurance in Sudan, Iran, and Saudi Arabia is provided exclusively in accordance with Islamic law, although each country has implemented different models of Islamic insurance. In accordance with the mentioned report, Saudi Arabia has a 44% share of the world Islamic insurance market. The report also states that, within the Gulf Cooperation Council, Saudi Arabia is the only country where all insurance companies operate in accordance with Shariah principles, while the shares of Islamic insurance in other member countries are as follows: 23% in Kuwait, 15% in Oman, 14% in Bahrain, 8% in the United Arab Emirates, and 8% in Qatar. At the end of 2022, the total share of the GCC region in the global Islamic insurance market was 55.7%, while the total contribution paid by policyholders of Islamic insurance companies operating in this market was 16.7 billion USD. Despite significant growth, the share of Islamic insurance companies in the total assets of the Islamic financial services industry was only 0.9% in 2022. Investigating the demand for insurance in fourteen Asian countries, Akhter and Khan (2017) observed that the Asian financial crisis in 1997 and the global economic crisis that emerged at the end of 2007, as well as economic growth in certain Asian countries, lead to significant growth in demand for conventional and Islamic insurance products as instruments for risk management. The authors also noted that Saudi Arabia has the largest contribution to the development of Islamic insurance.

According to data published by Swiss Re (2021), Saudi Arabia ranked as the 39th largest insurance market in terms of total premiums paid in 2020 among the countries included in the research. In the non-life insurance sector, Saudi Arabia held the 25th position, just after Denmark. It is also important to note that Saudi Arabia's population is six times larger, and its GDP is more than double that of Denmark.

To investigate the profitability determinants of Islamic insurance companies operating in the largest Islamic insurance market

in the world, it is crucial to understand how these companies function and what their main characteristics are. One of the main characteristics of the original Takaful model is that companies have a Shari'ah board; however, cooperative companies in Saudi Arabia are not obligated to establish such a supervisory body. Furthermore, in the core Takaful model, companies are required to align their investment activities with Shari'ah rules, meaning they can only invest in securities, bank accounts, or other assets that are Shari'ah-compliant. In contrast, cooperative insurance companies in Saudi Arabia are not subject to such regulatory restrictions (Hemrit, 2020).

In 2024, the Society of Actuaries, the world's largest actuarial professional organization, published a paper that investigates Islamic insurance as an alternative approach to traditional insurance. The authors highlight a key feature that distinguishes Islamic insurance companies from conventional insurers: the profit-sharing model between participants and shareholders, which does not exist in conventional insurance (Sikander, 2024). In cooperative companies, the majority of surplus is distributed to shareholders, and policyholders are entitled to only the remaining 10%, even though, according to Shari'ah principles, the whole surplus should be distributed exclusively to policyholders. In the event of a deficit in the participants' risk fund, that is, if participants' contributions together with investment profits are insufficient, the insurance company shall provide financial assets to participants to cover operating expenses and claims (Umut & Akkurt, 2022). As policyholders' funds shall be segregated from the shareholders' funds, the income of investment operations must also be segregated. Additionally, the investment profit or loss of participants is a crucial component of surplus (deficit) of participants' risk fund. Given its characteristics, the cooperative model can be viewed as a form of mutual insurance similar to that used in Europe. Thus, understanding how a cooperative insurance company operates can enhance our understanding of mutual insurance companies, which, according to data of AMICE (2023), accounted for up to 33% of the European insurance market in 2022.

One of the main characteristics of the insurance sector in Saudi Arabia is its highly underdeveloped life insurance market. The share of life insurance contributions in total premiums was only 2.9% in 2020 and 3.5% in 2022 (Swiss Re, 2023). Gaganis et al. (2020), in their research investigating 44 countries from 2000 to 2008, reveal a negative effect of the growth of the Islamic population on the development of the life insurance market. The extent to which this applies to Saudi Arabia also depends on the level of social protection in the country, as well as the ability to harmonize the operations of life insurance companies with the religious beliefs of the population. Based on the assumption that, in addition to religious convictions, business stability is also important for the development of the life insurance market, one of our goals is to examine whether there is a significant difference in profitability between cooperative insurance companies that provide only non-life insurance services and those that offer life insurance services as well.

As we focus on analyzing the profitability of cooperative insurance companies, decision-makers can use our results to define their strategic and operational plans and identify aspects of their operations that need improvement to achieve better financial performance. Given that Shari'ah-compliant insurers have also emerged in Europe, analyzing the characteristics of Islamic insurance companies is important for understanding competitive advantages, too. Additionally, other Islamic insurance companies can use this study to consider potential changes in their operating policies, particularly regarding surplus distribution, which could enhance profits for shareholders. Furthermore, policymakers at conventional insurance companies can adopt certain aspects of the cooperative business practices described in this study (such as implementing a surplus-sharing system among policyholders), to enhance their competitiveness.

1. Theoretical background

The profitability of insurance companies established as joint stock companies, mutual insurers, or as Islamic insurance companies can be measured with several indicators. Based on the results of results of previous research and the characteristics of cooperative companies in this study as profitability indicators, we use return on assets (ROA), return on equity (ROE) and earnings per share (EPS). In accordance with the aims and objectives of this study, in this section, we will discuss the theoretical and empirical studies of profitability indicators for

Islamic insurance companies in the 21st century. Nurbaya and Alam (2019) used multiple ordinary least square (OLS) regression to analyze factors affecting Islamic insurance profitability from 2011 to 2017, focusing on Sinar Mas Islamic Insurance in Indonesia. Based on the results, they concluded that operational costs have a positive impact and claims expenses have a negative and significant impact on profitability. Suherman et al. (2019) investigated the financial performance of Islamic insurance companies in Indonesia. The authors collected data for the period of 2012–2018 and used return on assets (ROA) as an indicator of financial performance. Based on the results obtained by the model of ordinary least squares (OLS) regression of panel data, company size has a significant and positive impact, whereas leverage and age have insignificant impact on the profitability of Islamic insurance companies.

Ibrahim et al. (2020) investigated the financial performance determinants of Takaful operators in Malaysia from 2007 to 2016. The authors used return on investment as a measure of financial performance, and based on the results of random effects regression model of panel data, they concluded that liquidity has a significant and positive impact on the profitability of Takaful operators, while the effects of other variables used in the study (profit or interest rate, equity return, liquidity, company size, underwriting risk, and Retakaful dependence) were insignificant.

In their study, Ullah et al. (2021) aimed to examine the determinants of profitability of Takaful and traditional insurance companies in Pakistan from 2003–2013. The analyzed period is divided into three phases: pre-crisis phase (2003–2006), the period during the crisis (2007–2009), and post-crisis phase (2010–2013). According to the authors, macroeconomic factors (GDP and inflation) have no significant impact on the profitability of the insurance sector in all three phases, whereas industry-specific variables (company size, leverage, and liquidity) have a miscellaneous effect on the profitability in different phases. Company size has a negative and significant impact in the pre- and post-crisis phases but has a positive impact during the financial crisis. Liquidity has a positive and significant impact on the profitability of Takaful companies in all three phases but has a significant (and negative) effect on traditional insurance companies only during the pre-crisis phase. On the other hand, leverage has a significant and negative impact on the profitability of Takaful companies during the crisis and in the post-crisis phase, whereas in the case of traditional insurance companies this factor has a significant (and positive) effect only in the post-crisis phase. Nizar and Falikhatun (2021) investigated the effect of Islamic intellectual capital on the financial performance of 41 Islamic insurance companies in the Middle East and Southeast Asia during the period of 2016–2019. As a measure of financial performance, they used return on equity (ROE) and found that structural capital efficiency has positive, capital employed efficiency has negative, and human capital efficiency has insignificant effect on the financial performance of Islamic insurance companies.

Sallemi and Zouari (2022) investigate the impact of chief executive officer (CEO) characteristics on the performance of Takaful insurance providers with distinguishable Muamalah contracts (wakalah and hybrid), while in their 2023 research paper, they examine the effects of Shari'ah board characteristics (Shari'ah board size, cross-membership, qualifications, and reputation) on the same type of insurers. In 2024, these authors published a paper that examines the effects of external audits, policyholder satisfaction, and socially responsible business operations on the financial performance, measured by ROA, ROE, and ROI, of 30 Takaful insurance companies operating in Southeast Asia (SEA) and Gulf Cooperation Council (GCC) markets during the period from 2011 to 2021.

Since we focus on companies operating in Saudi Arabia while researching the Islamic insurance market, we will especially emphasize research papers that focus on this market. Guendouz and Ouassaf (2018) investigated the main internal factors affecting the profitability of the six largest Islamic insurance companies in Saudi Arabia. In this research, profitability is measured with return on policyholders' assets. They used data collected from quarterly reports with a study period of 2010–2016 and applied pooled ordinary least squares (POLS), fixed effects, and random effects methods. The results indicate that age, company size, written premium growth rate, and loss ratio all have a significant effect on profitability, but it is important to note that the effects of these factors are positive in some cases and negative in others.

Hemrit (2020), based on a dynamic panel generalized method of moments (GMM), investigated the financial performance of Islamic insurance companies in Saudi Arabia covering the period of 2013–2017 with quarterly collected data. The author used net premium written, earning ratio, and profit margin as indicators of financial performance and stated that company size, insurance penetration, and risk reporting have significant and positive effects on the financial performance of analyzed companies, while book-to-market and board size have significant negative effects. Kantakji et al. (2020) examined the financial performance of 53 general Islamic insurance companies in Saudi Arabia, Malaysia, the United Arab Emirates, Qatar, and Pakistan with data collected for the period of 2010–2015. They used net investment income and investment yield as financial performance indicators. Based on a fixed effects model of unbalanced panel data, they found that company size, GDP per capita, equity returns, and interest rate have a significant and positive effect on the financial performance of Islamic insurance companies, whereas liquidity and retakaful dependence are negatively related to performance.

Al-Amri et al. (2021) emphasized the differences between specific organizational forms of Islamic insurance companies: operators that use wakalah (fee-based) and mudharabah (profit-sharing) model in 19 countries, including Saudi Arabia, during the period 2004 to 2009. A wakalah (fee-based) model means that the operator charges a predetermined fee for its services, which does not depend on the profitability of the Takaful insurance company and does not include profit-sharing from investment activities. In contrast, under the mudharabah (profit-sharing) model, the Takaful operator is allowed to share in the profit of the policyholders. The authors found that companies that use mudharabah (profit-sharing) model have higher performance scores than those using the wakalah (fee-based) model. Additionally, they concluded that a strategic focus (focusing on core business) is superior to conglomeration in terms of firm efficiency, performance (ROA, ROE) and insolvency risk.

Cahyandari et al. (2023) investigate different types of Islamic insurance companies: mudharabah, modified mudharabah, wakalah, hybrid, and Waqf models. The authors, based on a systematic literature review consisting of 774 research papers published between 2010 and 2022, emphasize that there is a difference in profitability between the mudharabah and modified mudharabah models. It should be noted that the modified mudharabah model includes a share of the takaful operator in the takaful fund surplus, just like in the case of cooperative companies.

As Sallemi and Zouari (2024) highlight, the surplus distribution policy is of particular importance. On the other hand, in the cooperative model underwriting surplus is the main source of the operator's fee and shareholders' profit. So, when analyzing the profitability of Islamic insurance companies, this distribution policy should be considered, but in earlier studies that focus on Islamic insurance surplus distribution is not statistically analyzed. According to that, this study aims to fill this gap and highlight the importance and effects on financial performance of surplus and its distribution in cooperative insurance companies.

2. Research methodology

In accordance with the research's aim, we form panel data series using quarterly collected data of 28 Saudi cooperative insurance companies from 2012 to the second quarter of 2020 (T = 34). Microeconomic data are obtained from quarterly financial reports of the selected companies, while macroeconomic data are collected from public databases. Thus, the study includes 952 observations for each variable that we use to form balanced panel data series with three dependent and 14 independent variables. Dependent and independent variables are defined based on the results of earlier studies with an aim to include the most important aspects of the financial and income statements that help to uncover where cooperative companies should focus to improve their financial performances. In addition to that, we use the operator's fee as an independent variable, which is not used in earlier studies, although this is one of the main aspects of Islamic insurance for two reasons: i) in the cooperative model it includes a given portion of underwriting surplus, which in other Islamic insurance models is not the case; and ii) operator's fee is one of the major sources of shareholders' income, so from the side of the company, it is important to define a fee, that can provide the necessary profits. As profitability is measured with three indicators: ROA, ROE, and EPS, we use data to build three models with the use of dependent and

Tab. 1: Dependent and independent variables

Variable	Calculation	Abbreviation
Dependent variables		
Return on assets	$\frac{\text{Net profit}}{\text{Total assets}}$	*ROA*
Return on equity	$\frac{\text{Net profit}}{\text{Equity}}$	*ROE*
Earnings per share	$\frac{\text{Net profit}}{\text{Number of shares}}$	*EPS*
Independent microeconomic variables		
Company size	Ln Total assets	Ln*TA*
Investment profitability	$\frac{\text{Net investment income}}{\text{Investments}}$	*INVP*
Investment income ratio	$\frac{\text{Net investment income}}{\text{Net premiums earned}}$	*INVIR*
Operator's fee	$\frac{\text{Surplus} + \text{Wakala fee} + \text{Mudharaba fee}}{\text{Net premiums earned}}$	*OF*
Expense ratio	$\frac{\text{OAE} + \text{Underwriting expenses}}{\text{Net premiums earned}}$	*ER*
Loss ratio	$\frac{\text{Net claims incurred}}{\text{Net premiums earned}}$	*LR*
Premium (contribution) growth	$\text{Ln}\frac{\text{Gross written premium}_t}{\text{Gross written premium}_{t-1}}$	*P(C)GR*
Risk exposure	$\frac{\text{Technical reserves}}{\text{Gross written premium}}$	*RIEXP*
Capital adequacy	$\frac{\text{Equity}}{\text{Total assets}}$	*CA*
Reinsurance dependence	$\frac{\text{Reinsurance ceded}}{\text{Total assets}}$	*RED*
Risk retention	$\frac{\text{Net written premium}}{\text{Gross written premium}}$	*NRR*
Specialization (dummy)	0 general 1 composite and life insurance	*BUSINESSID*
Independent macroeconomic variables		
Interest rate	Interbank offered rate level	*IBOR*
Equity returns	$\frac{SMI - SMI_{t-1}}{SMI_{t-1}}$	*SMI*

Note: Surplus is the share of the insurance company in the surplus of the policyholders' risk fund; OAE – operating and administrative expenses; SMI – stock market index.

Source: own

independent variables that are given in Tab. 1. Dependent variables are profitability indicators, while explanatory variables are grouped into microeconomic and macroeconomic variables. Microeconomic variables are defined by company-specific factors, whereas macroeconomic variables include financial sector-related factors that affect the investment performance of the insurers.

In accordance with the aim of the paper, we define the research hypothesis as follows:

H: Profitability of cooperative Islamic insurance companies is primarily determined with the effects of operator's fee, expense ratio, loss ratio and specialization.

Studies that investigate profitability determinants of insurance companies mostly use estimators that are based on panel data regression. Which estimator we should use depends on the error structure of the analyzed data. In other words, to avoid inconsistency and biased parameter estimation, it is necessary to use the correct estimator that fits the characteristics of our data. Thus, as a first step, stationarity, autocorrelation, heteroscedasticity, and cross-sectional dependence must all be tested. In addition, we must determine whether to use fixed-effects (FE), random-effects (RE) estimator, or the method of pooled ordinary least squares (POLS), as well as check for multicollinearity (Titus, 2021). According to Blackwell (2005), if we have panel heteroscedasticity, cross-sectional dependence, and panel autocorrelation we should use panel-corrected standard errors (PCSE) instead of the FE and RE estimators, which are inadequate to use with the given model error structure. To use this estimator with fixed-effects, fixed-effect dummies should be included for each unit. PCSE estimator introduced by Beck and Katz is robust against cross-sectional dependence, heteroscedasticity, autocorrelation, and is also suitable to be used with small panel datasets (Millo, 2017).

As Millo (2017) states, PCSE covariance is defined in terms of the $E_i = E \ \forall \ i$ function of the residuals as:

$$E = \frac{\sum_n \hat{e}_n \hat{e}_n^T}{N} \tag{1}$$

where: $\hat{e}$ – the predicted residual.

A sufficient, but not necessary condition of PCSE estimator is that the covariance matrix is equal for all units of observation (Beck & Katz, 1996). As Beck and Katz (1995) state the PCSE estimator is based on the use of the ordinary least square (OLS) estimator, but the OLS errors are replaced with panel corrected errors. The PCSE method estimates the full $N \times N$ covariance matrix. Thus this estimate tend to be more accurate if the ratio T/N is higher, or in other words, if the number of the cross-section units is not too large compared to the number of observed time periods (Hoechle, 2007).

3. Results and discussion

3.1 Results

As shown in Fig. 1 in the observed period, the ROA indicator has a minimum

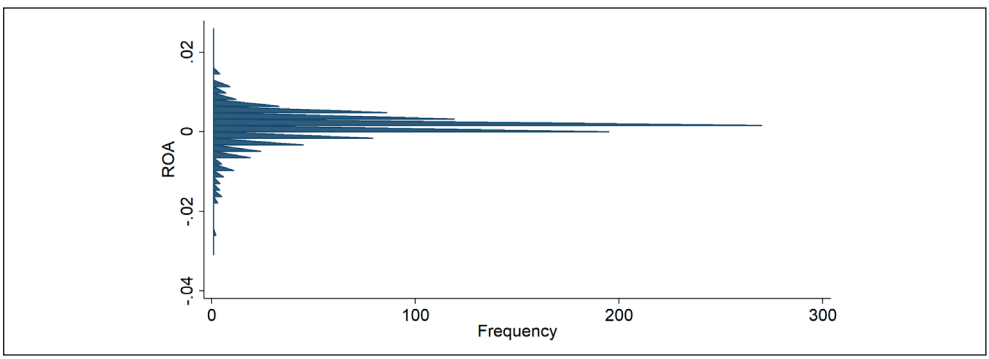

Fig. 1: ROA distribution of the observed cooperative insurance companies

Source: own

value of −0.031 USD and a maximum value of 0.025 USD. The mean value of ROA is 0.0008 with a standard deviation of 0.00049. Therefore, the value of ROA is between −0.0001 USD and 0.025 USD in 75% of the observations.

In the case of the ROE indicator presented in Fig. 2. the minimum value we observed is −0.335 USD, maximum value of this indicator is 0.076, while the mean value of return on equity is 0.0012 USD. The standard deviation of this variable is 0.028. The value of ROE indicator is between 0.0001 USD and 0.102 USD in 75% of the observations. Mutual insurers are characterized by low ROE values primarily because their owners are policyholders and not external shareholders.

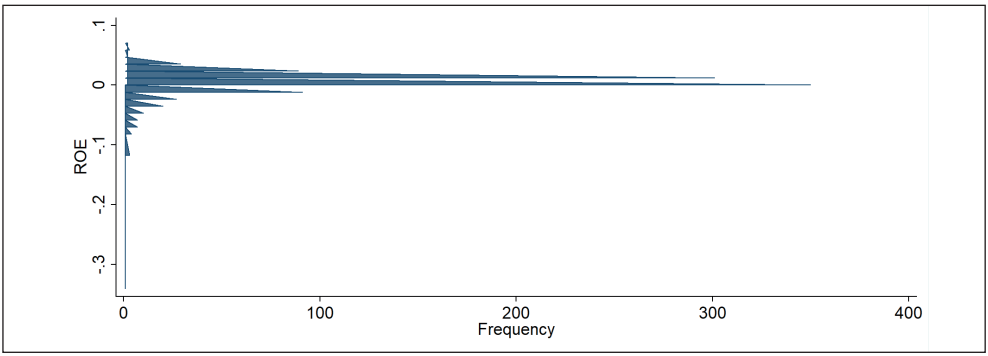

Fig. 2: **ROE distribution of the observed cooperative insurance companies**

Source: own

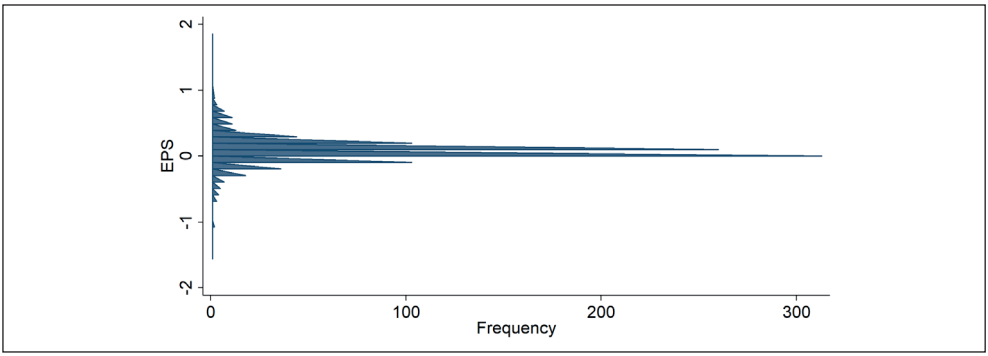

Fig. 3: **EPS distribution of the observed cooperative insurance companies**

Source: own

If earnings per share (EPS) is used as a measure of profitability, as it is shown in Fig. 3. the minimum observed value is −1.52 USD and the highest observed value is 1.9 USD. The mean value of this indicator is 0.052 with a standard deviation of 0.22, and the value of EPS is between 0 USD and 1.3 USD in 75% of the cases.

Results of Levin, Lin and Chu (LLC), Harris-Tzavalis (HIT) and Breitung tests of stationarity indicate that we cannot reject the null hypothesis that the series contains a unit root

in the case of company size and interest rate level. These variables, i.e., company size measured with the natural logarithm of assets and interest rate level measured with the level of interbank offered rate are stationary at first difference in accordance with LLC, HT, and Breitung tests. The Wooldridge test is used to test autocorrelation, and as we cannot reject the null hypothesis of the test, we can conclude that serial correlation of residuals does not exist in the case of ROA, ROE, and EPS models. The modified Wald statistics is used to check for homoscedasticity in all three cases (ROA, ROE, EPS). The null hypothesis of homoscedasticity (*H0*: $\sigma_i^2 = \sigma^2$ for all i) of the test is rejected in all cases, thus the data are characterized by panel heteroscedasticity. Cross-sectional dependence is tested with Pesaran's CD test. As all observed companies operate on the market of Saudi Arabia, it is unnecessary to check for cross-sectional dependence of macroeconomic variables, but as the null hypothesis of the test is rejected, the presence of cross-sectional dependence for company-specific variables should be noted when we choose the estimation method. Stationarity is also tested with second generation panel unit-root tests due to the presence of cross-sectional dependence. In accordance with the obtained test statistics of CADF, CIPS and Breitung (robust) tests, the null hypothesis that the series contain unit-root can be rejected for all variables, except for interest rate level, which is stationary at first difference. Due to heteroscedasticity, we use the Overid test in addition to Hausman-test to determine whether fixed or random effects model is appropriate. The results of these tests were identical, so the null hypothesis that the difference in parameters is not systematic is rejected in all three cases (ROA, ROE, EPS model). The presence of fixed effects is also indicated with the results of *F*-test: the null hypothesis is rejected in the case of ROA, ROE, and EPS models. Therefore, the fixed effects estimator is more efficient. The variance inflation factor (VIF) is higher in the case of company size, investment income ratio, and expense ratio. Considering the VIF values and the correlation coefficients of the explanatory variables, investment income ratio and company size are excluded from further analysis. As a result, all VIF values are below the tolerance limit (VIF > 10). The key characteristics of the data series are summarized in Tab. 2., while detailed test statistics are provided in Appendix (Tabs. A1–A9).

Based on the works of Blackwell (2005) and Camino-Mogro and Bermúdez-Barrezueta (2019) to handle heteroscedasticity and cross-sectional dependence when the differences in coefficients are systematic (presence of fixed effects) ROA, ROE, and EPS models of cooperative insurance companies' profitability should be estimated with the method of panel corrected standard errors (PCSE). As we stated above, due to multicollinearity, company size and investment income ratio are excluded from the final model, whereas interest rate level is included at its first difference to avoid non stationarity.

In the case of the ROA model, equity returns and premium (contribution) growth do not have a significant impact. Interest rate level change has only significance level of $p < 10\%$, while investment profitability, risk exposure, capital adequacy, and reinsurance dependence are only significant at significance level of $p < 5\%$. Parameter estimates of ROE model indicate that operator's fee, expense ratio, loss ratio, premium growth, capital adequacy, and specialization all have statistically significant impact, but premium growth is only significant at significance level of $p < 10\%$. In the case of EPS model, statistically significant effect was observed for operator's fee, expense ratio, loss ratio, risk retention, and specialization.

Tab. 2: Model characteristics

Model	Data series characteristics
ROA	Heteroscedasticity, cross-sectional dependence, fixed effects
ROE	Heteroscedasticity, cross-sectional dependence, fixed effects
EPS	Heteroscedasticity, cross-sectional dependence, fixed effects

Source: own

Tab. 3: Results of Beck and Katz's panel corrected standard errors (PCSE) estimator with fixed effects

Variable	*ROA*		*ROE*		*EPS*	
	Coefficient	*P*-value	Coefficient	*P*-value	Coefficient	*P*-value
INVP	0.0226	0.021**	0.0195	0.838	0.4830	0.265
OF	0.0164	0.000*	0.1004	0.000*	0.6137	0.000*
ER	−0.0161	0.000*	−0.1114	0.000*	−0.4574	0.000*
LR	−0.0268	0.000*	−0.1134	0.000*	−1.1459	0.000*
P(C)GR	0.0003	0.746	0.0105	0.070***	0.0212	0.618
RIEXP	0.0004	0.029**	0.0018	0.101	0.0100	0.156
CA	0.0117	0.039**	0.1109	0.006*	0.3521	0.196
RED	0.0456	0.03**	−0.0345	0.691	−0.4619	0.420
NRR	0.0066	0.007*	0.0127	0.453	0.2124	0.036**
D.IBOR	0.3569	0.063***	1.6906	0.246	14.7903	0.230
SMI	0.0037	0.457	−0.0157	0.675	−0.1323	0.683
BUSINESSID	−0.0148	0.000*	−0.0675	0.001*	−0.8048	0.000*
C	0.0325	0.000*	0.1625	0.000*	1.9306	0.000*
R^2	0.4663		0.3126		0.4019	

Note: * $p < 1\%$, ** $p < 5\%$, *** $p < 10\%$; the "*D.*" in variable names represents the first difference.

Source: own

Risk retention is statistically significant only for $p < 5\%$, while the other variables are significant at significance level of $p < 1\%$. Based on the results it can be stated that operator's fee, expense ratio, loss ratio, and specialization are significant at the level of $p < 0.01$ in all cases, while the effects of other factors are heterogeneous for the different models with different levels of significance. Therefore, the obtained results are in accordance with the hypothesis of the research. Based on the values of the coefficients of determination, we can say that 46.63% of variance in ROA, 31.26% of variance in ROE, and 40.19% of variance in EPS indicator can be explained by the independent variables.

3.2 Discussion

As we stated above, operator's fee, expense ratio, loss ratio, and specialization have significant effect whether we use ROA, ROE or EPS as an indicator of profitability with a significance level of $p < 0.01$. In some cases, significant effects were observed for other variables as well, but not in all models and not with a significance level of $p < 0.01$. As a result, we cannot reject the hypothesis of the research, thus, we can conclude that the profitability of cooperative Islamic insurance companies in Saudi Arabia is determined by operator's fee, expense ratio, loss ratio, and specialization. A positive effect on profitability has operator's fee, while expense ratio, loss ratio and specialization have negative impact. In our case, investment profitability does not have a statistically significant effect on ROE and EPS, while it has a statistically significant and positive impact on the ROA indicator. Hussanie and Joo (2019) state that investment profitability had a statistically negative effect on profitability. The authors explain the negative effect of investments with strict legal provisions concerning the investment activity of insurance companies. In the case of Saudi Arabia, all business provisions are defined based on Shari'ah rules, that highly affect and narrow the investment opportunities. Therefore, the statistical insignificance of this factor is a result of strict investment environment. On the other hand, it should be kept in mind that profitability is only one aspect

of the investment of insurance companies' assets. Therefore, safety, liquidity, and ensuring the preservation of the real value of funds should take priority. Easing the restrictions on investment opportunities to achieve higher investment profitability could lead to uncertainty in the realization of other investment principles. Statistically insignificant effects of interest rate level and equity returns are in accordance with the findings of Ibrahim et al. (2020), who also found that these variables have statistically insignificant effects.

To understand the significant and positive impact of the operator's fee, it is important to first understand how this fee is calculated. Unlike in the case of other Islamic insurance models, in line with the regulations in Saudi Arabia, the operator (cooperative insurance company) has the right to transfer the 90% of the surplus of policyholders' risk fund to the shareholders' fund. Thus, in addition to the share in investment income specified in Mudharabah contract, cooperative insurance company charges a certain percentage of that surplus. Therefore, the operator's fee includes investment income and a certain share in policyholders' surplus. As we see, surplus is the primary source of the operator's fee in the cooperative model, so the results of this research are in accordance with the results obtained in the studies of Fadah et al. (2021) and Sharma et al. (2021) who found that surplus has a significant and positive impact on profitability. A significant and negative impact of the expense ratio and loss ratio on profitability is to be expected, as an increase in these indicators indicates lower profitability in underwriting operations. If the sum of the expense ratio and loss ratio is greater than 1 (100%), it means there is no underwriting profit and suggests that cooperative insurance companies must improve cost efficiency to enhance financial performance. Nurbaya and Alam (2019), investigating Sinar Mas Islamic Insurance in Indonesia from 2011 to 2017, conclude that operational costs have a positive impact on profitability. This result may align with economic logic in the short term, where insufficient allocation for these costs leads to inadequate management of the insurance policy portfolio and an increased expense ratio. However, in the long term, the expected sign is negative. Hailegebreal (2016) states that premium growth has a significant and positive effect on the profitability of insurance companies. We found that this factor had positive effect in the case of ROE ($p < 10\%$) but was statistically insignificant in the case of ROA and EPS indicators. Thus, expanding business activities can provide the potential for better financial performance, but it is necessary to manage this growth effectively. As we stated, loss and ratio expense ratio lowers profitability, so premium growth can provide higher profitability only if it is adequate concerning the cost structure of provided services. We found that risk exposure has a positive effect, but it is statistically insignificant in the case of ROE and EPS. Our results are contradictory to the results of Vojinović et al. (2020) who state that risk exposure has negative effects on profitability. Reasons behind this difference could lie in the specific legal framework, lower share of life insurance (where mathematical and technical reserves provisions are stricter) and different insurance model. Therefore, technical reserves can serve as a factor for higher profitability if they are managed properly and if their growth is less than the growth of policyholders' contributions. The positive effects of capital adequacy are in accordance with results of Sasidharan et al. (2020). The positive impact of this factor indicates that a higher equity share in liabilities can provide higher profitability. We found that capital adequacy has no significant effect on the profitability of cooperative insurance companies when measured by EPS. According to our results, reinsurance dependence was statistically insignificant with a negative impact in the case of ROE and EPS indicators, while in the case of ROA this factor had a positive and statistically significant impact, which is in accordance with the results of Sasidharan et al. (2020). Thus, the advantages of a good reinsurance structure have not been used in Saudi Arabia. According to that, by improving the sector of reinsurance, cooperative insurance companies could operate more efficiently, and that could lead to the development of the whole insurance market ins Saudi Arabia. The results indicate that risk retention has a positive effect on profitability, which aligns with the findings of Isik (2021). On the other hand, the effects of this factor were not significant in terms of ROE, indicating that there is no statistical evidence to suggest that an increase in the share of retained premiums (contributions) in total written premiums (contributions) positively affects the ROE indicator. This data may suggest

the need to reevaluate the reinsurance policy. Along with the negative effects of the loss ratio, the results suggest that cooperative insurance companies could not increase their profitability, indicating a need for more efficient management of claims, expenses, and insurance contracts.

The significant and negative impact of specialization indicates that general cooperative insurance companies have a higher profitability than life or composite operators. In terms of specialization, the results of different studies are miscellaneous. Al-Amri et al. (2021) state that companies that provide only one type of insurance (life or general) are more efficient than those that operate as composite insurers. On the other hand, Kramaric et al. (2017) conclude that specialization has an insignificant impact on insurance companies' profitability. In our case, it should be noted that, according to the data of Swiss Re (2023), the share of life (family) insurance in the Saudi market in 2020 was only 3.29%. Therefore, the life insurance market in Saudi Arabia is less developed. In addition to that, to provide life insurance, cooperative insurance companies are obliged to form special reserves and funds, and the lower efficiency in the management of these funds may result in lower profit rates. On the other hand, the development of an insurance market depends on factors such as the social security system, statutory obligations to pay unemployment benefits, retirement, and demographic trends that are beyond the control of a specific company (Mitrašević et al., 2022). According to this, the development of life insurance in Saudi Arabia requires a general market strategy defined by policymakers, as well as more efficient management and more appealing products from life insurance companies. Furthermore, restrictions concerning investment opportunities as well as reinsurance should be improved for the future development of the insurance market in Saudi Arabia.

Conclusions

The study investigates the effects of company-specific and selected macroeconomic factors on the profitability of cooperative insurance companies in Saudi Arabia. The key feature of this Islamic insurance model is the pre-defined method of distributing the realized profits. To investigate the determinants of profitability of the selected companies, we used return on assets, return on equity, and earnings per share as profitability indicators, and company size, investment profitability, investment income ratio, operator's fee, expense ratio, loss ratio, premium growth, risk exposure, capital adequacy, reinsurance dependence, specialization, interest rate, and equity returns as explanatory variables. In accordance with the presence of heteroscedasticity and cross-sectional dependence, we used Beck and Katz's panel corrected standard error (PCSE) estimator, and the results suggest that all three profitability indicators of cooperative Islamic insurance companies are determined by operator's fee, expense ratio, loss ratio, and specialization.

Operator's fee has a positive and significant effect as one of the most important determinants of the profitability of cooperative insurance companies. Despite its important role in Islamic insurance, operator's fee is not included in earlier studies. Thus, the findings of this study serve as new evidence that indicates that operator's fee has a key role in the organization of Islamic insurance, whether it includes underwriting surplus or not. As we stated above, expense ratio, loss ratio, and specialization all have negative impact. That means to ensure profitability, decision-makers in these companies must pay special attention to the efficiency of their risk management, claims management, and cost management. The negative impact of specialization means that life insurers in Saudi Arabia have a lower profitability. As we stated, the life insurance market of Saudi Arabia is less developed, so in order to improve life insurance profitability, it is necessary to increase the whole life insurance market's efficiency, which can be a strategic goal not only for companies, but also for policymakers. On the other hand, it is necessary to improve investment regulatory framework to strengthen the potential of Islamic insurance companies for higher investment profitability. Surplus distribution policy can be interesting not only for cooperative insurance companies, but also for Takaful operators that use other models and mutual insurance companies, too. In most countries, Takaful operators are not allowed to participate in surplus distribution, but as it is shown in this study, incentive fees (as a share in surplus) can serve as a source of better financial performance. In the case of insurance companies that operate as joint stock companies or mutual insurers, the distribution of a certain percentage

of surplus among policyholders can increase their competitiveness.

In accordance with the above stated, surplus distribution policy should be discussed not only among cooperative companies, but also among Takaful companies to define a strategy that can help to increase profitability, and conventional insurance companies to define a strategy that increases competitiveness and, with that, leads to higher profitability.

Our research is relevant to insurance regulators in USA and some countries in Europe where Islamic insurance has taken root. In addition, our research is relevant to regulators in the USA and in some European countries where Islamic insurance has taken root. Furthermore, it is also important considering that Swiss Re and Munich Re have established Shari'ah-compliant reinsurance entities in the Middle and Far East. Our further research will focus on the effects of modern technologies on the Islamic insurance market.

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Appendix

Tab. A1: First generation stationarity tests

Variable	LLC		HT		Breitung	
	Statistic	*P*-value	Statistic	*P*-value	Statistic	*P*-value
ROA	−8.9849	0.0000	0.1866	0.0000	−13.7359	0.0000
ROE	−10.7727	0.0000	0.0322	0.0000	−10.6908	0.0000
EPS	−6.8691	0.0000	0.1935	0.0000	−13.4155	0.0000
Ln*TA*	−5.0938	0.0000	0.6579	0.0000	2.3575	0.9908
INVP	−9.4752	0.0000	−0.0568	0.0000	−14.0050	0.0000
INVIR	−3.7440	0.0000	−0.2169	0.0000	−6.7068	0.0000
OF	−35.7811	0.0000	−0.4803	0.0000	−12.3603	0.0000
ER	−16.0002	0.0000	0.5488	0.0000	−5.2475	0.0000
LR	−8.0474	0.0000	0.0470	0.0000	−10.0776	0.0000
P(C)GR	−16.7113	0.0000	−0.5352	0.0000	−13.8435	0.0000
RIEXP	−9.3250	0.0000	−0.0114	0.0000	−12.1360	0.0000
CA	−2.3660	0.0090	0.6236	0.0000	−3.2965	0.0000
RED	−8.7359	0.0000	−0.0103	0.0000	−9.9112	0.0000
NRR	−7.8800	0.0000	0.2409	0.0000	−8.1236	0.0000
IBOR	−3.8738	0.0001	0.9231	0.6983	−3.7560	0.0001
SMI	−5.7504	0.0000	−0.2914	0.0000	−10.9353	0.0000
***D.*lnTA**	−13.2120	0.0000	−0.3430	0.0000	−18.3814	0.0000
D.IBOR	−1.5450	0.0000	0.5164	0.0000	−14.0396	0.0000

Source: own

Tab. A2: Second generation stationarity tests

Variable	CADF		CIPS		Breitung (robust)	
	Statistic	*P*-value	Statistic	*P*-value	Statistic	*P*-value
ROA	−3.723	0.000	−4.687	0.000	−9.207	0.000
ROE	−3.960	0.000	−4.843	0.000	−10.260	0.000
EPS	−3.457	0.000	−4.694	0.000	−8.963	0.000
Ln*TA*	−2.460	0.000	−2.846	0.000	−3.789	0.000
INVP	−3.569	0.000	−5.099	0.000	−9.223	0.000
INVIR	−2.755	0.000	−4.535	0.000	−0.194	0.000
OF	−3.898	0.000	−4.415	0.000	−0.768	0.000
ER	−2.938	0.000	−3.604	0.000	−5.170	0.000
LR	−3.441	0.000	−4.351	0.000	−5.760	0.000
P(C)GR	−5.096	0.000	−6.046	0.000	−5.094	0.000
RIEXP	−3.082	0.000	−4.403	0.000	−5.932	0.000
CA	−2.389	0.000	−2.841	0.000	−5.854	0.000
RED	−3.718	0.000	−4.892	0.000	−9.216	0.000
NRR	−3.147	0.000	−4.090	0.000	−7.688	0.000
SMI	−7.862	0.000	−3.993	0.000	−2.220	0.013
CPI	−2.294	0.174	−0.891	0.187	−1.776	0.038
D.CPI	−5.535	0.000	−3.170	0.001	−5.229	0.000

Source: own

Tab. A3: Autocorrelation (Wooldridge test; *H0*: There is no serial correlation in panel series)

Model	*F*-statistics	Prob > *F*
ROA	0.315	0.580
ROE	2.628	0.117
EPS	2.539	0.123

Source: own

Tab. A4: Heteroskedasticity test (Wald statistics; *H0*: $\sigma_i^2 = \sigma^2$ for all *i*)

Model	Chi² (12)	Prob > chi²
ROA	2,072.890	0.000
ROE	32,467.600	0.000
EPS	10,988.230	0.000

Source: own

Tab. A5: Pesaran CD test for cross-sectional dependence

Variable	CD-test	*P*-value	Correlation	Abs (corr)
ROA	11.213	0.000	0.100	0.190
ROE	12.268	0.000	0.110	0.190
EPS	16.209	0.000	0.140	0.210
Ln*TA*	24.083	0.000	0.210	0.470
INVP	9.374	0.000	0.080	0.180
INVIR	14.795	0.000	0.130	0.220
OF	10.539	0.000	0.090	0.180
ER	8.563	0.000	0.080	0.210
LR	15.223	0.000	0.130	0.200
P(C)GR	25.318	0.000	0.220	0.320
RIEXP	16.492	0.000	0.150	0.210
CA	15.598	0.000	0.140	0.310
RED	8.031	0.000	0.070	0.190
NRR	3.617	0.000	0.030	0.190

Source: own

Tab. A6: Hausman's specification test (*H0*: Difference in coefficients is not systematic)

Model	Chi^2 (12)	Prob > chi^2
ROA	56.640	0.000
ROE	41.710	0.000
EPS	21.550	0.028

Source: own

Tab. A7: Overid test

Model	Chi^2 (11)	Prob > chi^2
ROA	213.314	0.000
ROE	227.108	0.000
EPS	86.168	0.000

Source: own

Tab. A8: ***F*-test for fixed effects**

Model	*F*-value	Prob > *F*
ROA	3.980	0.000
ROE	2.570	0.000
EPS	6.150	0.000

Source: own

Tab. A9: **Multicollinearity (VIF) test (tolerance: *VIF* < 10)**

Variable	*VIF*	
LnTA	39.600	–
INVP	1.150	1.150
INVIR	236.540	–
OF	180.260	1.040
ER	85.010	1.160
LR	3.690	3.400
P(C)GR	1.320	1.320
RIEXP	4.420	4.010
CA	5.820	5.580
RED	2.310	2.180
NRR	13.690	8.500
GDP	1.930	1.920
IBOR	8.700	7.220
SMI	1.040	1.040
CPI	2.530	2.360
BUSINESSID	10.060	8.500
VIF	37.380	3.530

Source: own

The relationship between implicit moral hazard, corporate governance, and bank lending behavior

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Abstract: *Environmental, social, and governance (ESG) development has indeed changed the original economic operation status through diversified methods. The banking industry, especially under the guidance of ESG, reminds the banking industry that it should focus on regulatory conditions such as lending objects with ESG operating characteristics. In terms of corporate governance, the banking industry needs to adopt high self-management standards for business development. This paper uses the panel threshold model to measure the regional moral hazard of 30 firms in the Taiwan bank industry from 2007 to 2018. The research shows that banks with high regional loan concentration ratios have evidence of moral hazard and a significant asymmetric effect in the regional loan concentration ratio in the bank industry. Based on this, the bank's high regional (NPL ratio) is used to measure the level of the bank's credit risk and quality of outstanding loans, which requires strengthening loan quality, the optimum concentration of loan weight, promoting the establishment of the effectiveness of the ownership structure and enhancing the development of management ability. Due to Taiwan's banking industry's overly competitive business environment, loan concentration and moral hazard lending practices have emerged. There is an apparent correlation between the development of the banking industry and an extremely competitive business environment. Therefore, how to have healthy competition in the banking industry instead of vicious competition is worth learning from other countries. This paper argues that creating a competitive banking environment is crucial. To target loan recipients, the banking industry should leverage its business expertise, integrity, and business ethos in line with international trends, such as ESG development trends. Regarding corporate governance, banks should be able to use equity structures, compensation system management, and internal management measures to establish more competitive professional banks.*

Keywords: *Moral hazard, loan concentration ratio, panel threshold model.*

JEL Classification: *C23, D24, G21.*

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Introduction

In recent years, the banking industry's environmental, social, and governance (ESG) practice has attracted global attention. Taiwan's banking industry has faced many challenges, especially illegal lending, or business malpractices, which are the focus of news reporting. The banking industry does not seem to be under pressure from these public opinions. Hence, these phenomena are continuously happening. The banking industry is still willing to take risks to meet the challenges of moral hazard. There may be many banks that are on the verge of moral hazard, and these banks are only hidden in facts that have not yet been discovered. What is more critical for the banking industry: high moral standards or bank value? For the banking industry, it may not be an easy option. In particular, in the face of banks with different business competitiveness, it may be an option that is difficult to balance. In recent years, emerging risks have received significant attention from the banking industry. In 2003, the OECD mentioned the concept of emerging risks based on (Hood, 2005). It mainly studied the risks posed to international investment from population changes, changes in the ecological environment, technology, and social structure, and how to change the path of risk transmission, leading to the generation of overall systemic risks.

Therefore, the three significant ESG-oriented risks have become key areas of emerging risks in the financial industry in recent years. Large international banks have broken away from traditional risk thinking models and moved towards cross-domain diversified simulations of emerging risk scenarios, integrating ESG design elements and assessing the impact of banks on the effects and impact of credit risk. Taiwan's banking industry also caters to these changing trends. The degree of risk inclusion in credit objects has been changing, and a more comprehensive consideration has been given to the types of risks that must be covered.

In response to the risk management requirements of resilience and sustainable development, the banking industry will establish a cross-department risk management mechanism to strengthen the risk decision-making linkage management mechanism of "responsible lending" and "responsible investment" in the future and the implementation of internal risk management mechanisms.

Therefore, it is necessary to show that the corporate governance of the banking industry itself has a beneficial effect on the internal management and control mechanism. Prowse (1998) further analyzed that the ownership concentration of companies in East Asian countries is higher than that of other regions, which leads to imperfect corporate governance mechanisms and is one of the main factors leading to the financial crisis. It also shows the importance of overall corporate governance. Kirkpatrick (2009) shows that the board of directors' oversight responsibilities and reliability risk management are essential to the banking industry. In particular, the banking industry's funds mainly come from the general public and operate with high financial leverage. It faces the professional position that implementing corporate governance can effectively control the bank's operational and financial risks; more importantly, the banking industry should pay attention to the integrity of the management – professional ethics to reduce moral hazard problems caused by information asymmetry.

Francis et al. (2019) state that bank monitoring aims to reduce credit risk by restricting opportunistic behavior among borrowing firms about the moral hazard problem, and bank intervention following covenant violations provides a way to influence firm decisions. From the ongoing financial malpractices in the banking industry or corporate governance violations, it seems that the degree of profitability of the banking industry is higher than the occurrence of moral hazard. However, from the competent authorities' attitude towards the banking industry, it seems that the ethical standards of the banking industry should be more profitable.

Indeed, the economic shocks such as the low interest rate era and the financial tsunami have challenged the banking industry. Especially in the low-interest-rate environment, the profit margin of the central spread of the banking industry has been squeezed a lot. In particular, the banking industry is in a competitive market, and the businesses that banks can engage in are very homogenous. In such a highly challenging business environment, it is more practical business functions, such as the development of more convenient channels or tools for borrowing. It is also the reality of the competition in the banking industry.

Since the banking industry has entered a competitive industry, if banks want to have

brilliant performance results, they must travel on the edge of the regulations, and even need unscrupulous means to win customers' support. In this way, the requirements of the high-level management of the banking industry for the performance of employees have become an essential goal for the banking industry to become an annual performance. Even if the employees who are unable to complete the target will be forced to leave, it is already a hidden rule in the banking industry.

Bank-specific and ownership structures are the measures and functions of the banking industry for management. The purpose of the banking industry is to strengthen operational measures and ownership structure to demonstrate business value and strong corporate governance. However, it is clear that in the past few years, the banking industry has experienced multiple loan fraud and moral hazard cases, which seems to highlight that some banks may not function in the operation management and ownership structure. When the banking industry is facing profit, corporate governance and moral hazard are intertwined, testing the true functions of bank management mechanisms and corporate governance. Therefore, the banking industry directors and high-level management departments face two essential choices. One part of the directors and senior management groups tend to attach importance to moral hazard attitudes, while bank profitability is second. The other part is that directors and high-level management may class total bank profits. As the primary goal, the remuneration of directors and senior management is directly linked to bank value.

Most of the literature in the past discussed whether the moral hazard of the banking industry has a moral hazard or how the case illustrates the type of moral hazard. Different from the literature in the past, this study suggests that there seem to be exciting signs between moral hazard and bank value. Extensive scope discussions are necessary to capture the bank's attitude toward moral hazard from the relationship between moral hazard, ownership structure, and bank performance.

Furthermore, consider the changes in the relationship between different threshold types of the banking industry's moral hazard, ownership structure, and bank performance. In particular, the number of banks has grown in recent years, and the general public's perception is that probability is the primary goal for new banks. Therefore, it is considered that the bank value of moral hazard in whether lending behavior has different effects on moral hazard; it still needs to be empirically studied and discussed. On the other hand, in the past, it was rarely discussed whether the equity structure and bank-specific of banks with moral hazard contributed to bank value. Therefore, this study will further integrate moral hazards, bank-specific and ownership structures, and propose operational recommendations for the competent authorities and the banking industry.

Over the past few years, as Taiwan's banking industry has experienced a highly competitive environment, fraud cases related to loans that violated the bank's integrity principles have occurred one after another, which in turn has affected banks' high overpayment ratios and the public's doubts about the integrity of the banking industry. The competent authorities require the banking industry to strengthen its corporate governance measures yearly through publicity and legal policies. In particular, the legal policy emphasizes corporate governance that follows international trends measures, including companies with professional ownership structures, operational transparency, board operations, operational transparency, and experienced managers.

Since the general public has high standards and expectations for the quality of banking industry operations, it is necessary to explore the awareness of possible moral hazard risks in the banking industry. Follow the policies related to the above governance measures, including ownership structure, and bank characteristics, and try to achieve empirical results by addressing moral hazards. This study will help the bank's stakeholders, including depositors, bank shareholders, bank wealth management, and other related customer groups, to have a clearer understanding of the potential risks that banks may have and to recognize the importance of corporate governance measures in the banking industry.

The banking industry plays an essential role as a financial intermediary in society. In addition to financial professional capabilities, banks must gain the public's trust. In recent years, corporate social responsibility has gradually attracted international attention. Feature management, corporate governance, risk management, etc., are

responsibility items that have been magnified and examined in bank operations. To this end, regarding legal policies, Taiwan's competent authorities adopt corporate sustainable development measures to strengthen the banking industry and society – responsibility standards.

Currently, the banking industry is still implementing and improving operating conditions. Therefore, due to data integrity considerations, this study will arrange the research period from 2007 to 2018, trying to observe the inherent changes in bank operating values during the research period. This study believes that the banking industry should adopt higher standards of strategic measures and even voluntarily incorporate high-standard legal policies and guidelines to coordinate the banking industry's operations to impact the bank's operating value positively. On the one hand, the banking industry formulates ESG legal policies with a voluntary attitude and higher standards to reduce social concerns about moral hazard. On the other hand, a high level of trust in the bank's image is built with high transparency.

The remainder of the paper is organized as follows. Section 1 describes measures of moral hazard and lending behavior on the bank value and the nature of this study's tests. Section 2 presents the descriptive statistics of our data and panel threshold model. Section 3 examines bank-specific ownership structure and bank value and explores how the NPL ratio and lending behavior threshold are related to bank value and moral hazard. The paper closes with a brief conclusion.

1. Theoretical background

The banking industry is an essential channel for enterprise and individual borrowing. Therefore, the environment of different economic conditions has a significant impact on the lending conditions of the banking industry. Hence, it is essential that the banking industry faces the growth of operational performance and creates a profitable return. It is a crucial business goal between banks, managers, and employees. In the face of a low interest rate environment, the banking industry often has many choices regarding moral hazards and operational performance. Going further, it is uncertain whether moral hazards will occur in the future, but manager compensation and employee dividends are expected to be profitable, and can also achieve annual operational goals.

It is true that most of the past literature used the NPL ratios to measure credit risk and supported the idea that the NPL ratios have a significant impact on banking industry operations. This study extends the discussion of moral hazards and is oriented toward structural phenomena related to the banking industry. Therefore, we can capture possible moral hazard issues through the structural performance of different NPL ratios, ownership structures, and lending behaviors. For example, in a highly competitive market environment, the banking industry will choose to achieve short-term bright lending performance, which lending behaviors may affect high NPL ratios in the future.

It seems that there may be a moral hazard in the future of the banking industry, but managers and employees are willing to risk engaging in illegal lending, which is a profit-making incentive. Therefore, we analyze the following structural literature on the aspects of moral hazard, bank value, operational performance, and corporate governance.

We also observe discussions by other scholars, e.g., Ben-David et al. (2020), who find that distressed banks reduce their leverage ratios and risk indicators, which is inconsistent with the view that moral hazard incentives dominate leverage ratios and risk-taking policies of distressed banks.

Adegboye et al. (2020) show that sound corporate governance structures improve loan quality and bank stability. In addition, effective corporate governance mechanisms and bank supervision can help curb excessive risk appetite, which can harm possible performance and loan quality.

Pierret and Howarth (2023) discuss moral hazard as a multidimensional issue. From the perspective of moral hazard as a political concept, by comparing the understanding and application of the concept of moral hazard by the presidents of the Bundesbank and the European Central Bank, the article re-examines the views of moral hazard in the political and professional fields.

Thomas and Singh Thaku (2023) show that the moral hazard hypothesis is found not to hold for the given sample of Indian banks, suggesting that an increase in the non-performing assets NPA ratio does not potentially increase riskier loans for the sample banks. The paper finds empirical evidence that "too big to fail" banks may have incentives to take on higher risks and thus have higher non-performing asset ratios.

1.1 Literature review of moral hazard and bank performance

Researchers have recently discussed the relationship between moral hazard and operational performance, often exploring whether the banking industry has a moral hazard, market competition, and regional issues. For instance, Janda and Kravtsov (2018) focus on a close relationship between the level of risk-taking and the performance and efficiency of bank managers, which supports the theoretical argumentation of moral hazard. The results of Zhang et al. (2016) support the moral hazard assumption, suggesting that an increase in non-performing loan ratios will lead to higher-risk loans, which may lead to further deterioration in loan quality and financial system instability. Berndt and Gupta (2009) state that banks initiate and sell loans from low quality borrowers based on unobservable private information, or loan sales lead to reduced bank regulation and moral risk to borrowers. Mollah et al. (2017) find that due to the complexity of the product and the trading mechanism, the bank's governance structure enables them to take on higher risks and achieve better performance. Soedarmono et al. (2011) examine whether Asian banks are still vulnerable to moral hazard after the 1997 Asian crisis. The findings underscore that higher market forces in the banking market lead to greater instability.

From the above discussion of the relationship between moral hazard and bank performance, we find that there is a relationship between moral hazard and bank performance, because of competition, regional factors and other factors affecting moral hazard and bank performance.

Since the non-performing loan is an indicator valued by the competent authority, it is related to the soundness of the bank's operations. The relevant authorities will have more different policy measures for high or low NPL ratio. Moral hazard is a different challenge for banks with high or low NPL ratio. Therefore, we infer that banks with NPL ratio are more willing to challenge moral hazard to make a profit.

H1: There is a significant relationship between moral hazard and bank value, which is at the threshold of a non-performing loan.

1.2 Literature review of moral hazard and bank-specific ownership structure

Jiang et al. (2019) find that high-risk banks had executive compensation compared to low-risk banks before regulation in 2010. Hellmann et al. (2000) find that in a dynamic model of moral hazard, competition can undermine prudent bank behavior. Spong and Sullivan (2007) results show that the wealth and financials of managers and directors significantly affect their attitudes toward risk and the risk-return trade-offs of banks. Nier and Baumann (2006) say that while competition leads to higher risk incentives, the fierce competition in the national inter-bank market discipline more effectively suppresses these incentives. Crawford et al. (1995) observe the increase in the salary-related relationship in the banks with high capitalization rates, consistent with the incentives to provide wealth creation while increasing the sensitivity of compensation performance. Williams and Nguyen's (2005) findings support the privatization of banks and the abolition of state ownership on the grounds of economics. They suggest that the potential benefits of foreign ownership may take longer to achieve. For domestic private banks, the challenge is to improve bank efficiency. Belkhir's paper (2009) examines the interrelationship between ownership and board characteristics. There is a statistically significant relationship between perceived performance, insider ownership, and primary shareholder ownership. Samad and Hassan (2006) show strong evidence of the management talent market, a market where pay levels and structures match the competitiveness of the banking environment. The study of Magnan and St-Onge (1997) investigated how the relationship between bank performance and executive compensation is influenced by the discretion of executive management. In the case of high management discretion, executive compensation is more relevant to bank performance than management discretion. Kartadjumena and Rodgers (2019) show that Indonesian bank companies may only conduct corporate responsibility activities for their own benefit, which is an altruistic motivation that affects the company's financial performance decline. Corporate sustainability issues describe a weakening factor and a partial intermediary between executive compensation and financial health performance.

Recent results in the literature on ownership structure are precious. This means that the banking industry's emphasis on the bank value should be more professional, as it is an essential factor in improving overall

banking performance. In terms of moral hazard, as the banking industry is in a highly competitive environment, bank value is the focus of the banking industry.

Therefore, when faced with moral hazard, whether there is a trade-off between the ownership structures on moral hazard remains to be discussed. Furthermore, current banking development includes bank specifics. Due to different bank specifics, these banks may have different influences on the trade-off between and bank-specific and moral hazard in the face of bank value.

H2: There is a trade-off relationship between moral hazard, ownership structure, and bank specifics.

1.3 Literature review of executive compensation and bank performance

Uchida and Nakagawa (2007) noted that banks exhibit a cluster of lending behavior for specific industries. Sapienza (2004) showed that lending behavior by state-owned banks is affected by the electoral results of the party affiliated with the bank. Past literature shows that banks do have various lending practices and consider their lending behavior policies under many different factors. From the above literature, lending behavior is an essential key factor; the banking industry has always been especially concerned about the sustainability of bank values. Therefore, it is worth discussing whether lending behavior has a positive impact on bank performance. Furthermore, since the literature rarely discusses whether the lending behavior of different physique banks affects bank value, this paper considers the impact of moral hazard on bank value under different thresholds of lending behavior. This study summarizes the above literature and abstracts (Tab. 1).

H3: Lending behavior has an inverted U-shape effect on bank value.

H4: There is a significant relationship between moral hazard and bank value, which is at the threshold of lending behavior.

Moral hazard variables include lending growth rate and non-performing loan ratios; this study also captures their correlation through changes in these variables. Bank-specific variables include relationship credit ratio, management fees, and employee efficiency; this study also observes the overall impact of these variables on bank value.

Moral hazard variables include lending growth rate and non-performing loan ratios; this study also captures their correlation through changes in these variables. Bank-specific variables include relationship credit ratio, management fees, and employee efficiency; this study also observes the overall impact of these variables on bank value.

2. Research methodology

This model by Zhang et al. (2016) and Uchida and Nakagawa (2007) is derived from conventional theory and employs the dynamics data model to estimate correlations among moral hazard, ownership structure, and bank lending behavior. This paper sets up panels on 30 firms in the Taiwan bank industry from 2007 to 2018, and we take data from Taiwan Economic Journal (TEJ) sources. We construct an equation as follows:

$$\begin{aligned} \mathrm{Ln}TQ_{it} = {} & \beta_{1i}\ln LG_{it} + \beta_{2i}\ln NPL_{it} + \\ & + \beta_{3i}\ln RC_{it} + \beta_{4i}\ln MF_{it} + \beta_{5i}\ln EY_{it} + \\ & + \beta_{6i}\ln DS_{it} + \beta_{7i}\ln MH_{it} + \beta_{8i}\ln FC_{it} + \\ & + \beta_{9i}\ln DSR_{it} + \beta_{10i}\ln LC_{it} + \beta_{11i}\ln A_{it} + \varepsilon_{it} \end{aligned} \quad (1)$$

where: TQ_{it} – Tobin's Q; LG_{it} – lending growth rate; NPL_{it} – non-performing loan; RC_{it} – a relationship credit ratio; MF_{it} – the management fee ratio; EY_{it} – employee efficiency; DS_{it} – director's shareholding ratio; MH_{it} – the manager holding; FC_{it} – friendly corporate ownership; DSR_{it} – the director's salary ratio; LC_{it} – loan concentration ratio; A_{it} – the bank size.

We estimate Equations (1–2) using the panel approach that takes into consideration both firms i and year t, and ε_{it} what are the fixed effects, deterministic trends, and error terms, respectively.

González and Teräsvirta (2006) show that transition function $g(q_{it}; \gamma, c)$ is a continuous function of the observable variable q_{it} and is normalized to be bounded between 0 and 1, and these extreme values are associated with regression coefficients β_0 and $\beta_0 + \beta_1$. More generally, the value of q_{it} determines the value of $g(q_{it}; \gamma, c)$ and thus, the effective regression coefficients $\beta_0 + \beta_1 g(q_{it}; \gamma, c)$ for the individual i at a time t. The widely used transition function is a logistic specification as in Equation (3).

$$g(q_{it};\gamma,c) = \left[1 + \exp\left[-\gamma\prod_{j=1}^{m}(q_{it} - c_j)\right]\right]^{-1} \quad (2)$$

$$\text{with } \gamma > 0 \text{ and } c_1 \le c_2 \le \cdots \le c_M$$

Tab. 1: The literature review

Variable	Year	Study	Effect on firm value	Theoretical predicted sign(s)
Moral hazard variable	2018	Janda and Kravtsov (2018)	Negative	–
	2016	Zhang et al. (2016)	Negative	–
	2017	Mollah et al. (2017)	Negative	–
Bank-specific organizational structure	2007	Spong and Sullivan (2007)	Positive	+/–
	2009	Belkhir (2009)	Positive	+/–
	2006	Samad and Hassan (2006)	Positive	+/–
	2019	Kartadjumena and Rodgers (2019)	Positive	+/–
Lending behavior factors	2000	Ewert (2000)	Positive	+/–
	2004	Sapienza (2004)	Positive	+/–
	2007	Uchida and Nakagawa (2007)	Positive	+/–

Note: This paper was compiled with reference to the above-mentioned literature.

Source: own

A generalization of the PSTR model to allow for more than two different regimes is the additive model:

H1: There is a significant relationship between moral hazard and bank value, which is at the threshold of a non-performing loan.

H2: There is a trade-off relationship between moral hazard, ownership structure, and bank-specific. Set threshold variables: non-performing loan.

$$\begin{aligned}\mathrm{Ln}TQ_{it} &= \beta_{1i}\ln LG_{it} + \beta_{2i}\ln RC_{it} + \beta_{3i}\ln MF_{it} + \\ &+ \beta_{4i}\ln EY_{it} + \beta_{5i}\ln DS_{it} + \beta_{6i}\ln MH_{it} + \beta_{7i}\ln FC_{it} + \\ &+ \beta_{8i}\ln DSR_{it} + \beta_{9i}\ln LC_{it} + \beta_{10i}\ln A_{it}\,[\beta_{1i}\ln LG_{it} + \\ &+ \beta_{2i}\ln RC_{it} + \beta_{3i}\ln MF_{it} + \beta_{4i}\ln EY_{it} + \textstyle\sum_{j=1}^{\gamma}\beta_{5i}\ln DS_{it} + \\ &+ \beta_{6i}\ln MH_{it} + \beta_{7i}\ln FC_{it} + \beta_{8i}\ln DSR_{it} + \beta_{9i}\ln LC_{it} + \\ &+ \beta_{10i}\ln A_{it}]\, g(q_{it}^{j};\gamma, c) + \varepsilon_{it}\end{aligned} \quad (3)$$

H3: Lending behavior has an inverted U-shape effect on bank value.

$$\begin{aligned}\mathrm{Ln}TQ_{it} &= \beta_{1i}\ln LG_{it} + \beta_{2i}\ln NPL_{it} + \beta_{3i}\ln RC_{it} + \\ &+ \beta_{4i}\ln MF_{it} + \beta_{5i}\ln EY_{it} + \beta_{6i}\ln DS_{it} + \\ &+ \beta_{7i}\ln MH_{it} + \beta_{8i}\ln FC_{it} + \beta_{9i}\ln DSR_{it} + \\ &+ \beta_{10i}\ln LC_{it} + \beta_{11i}\ln LC_{it}^{2} + \beta_{12i}\ln A_{it} + \varepsilon_{it}\end{aligned} \quad (4)$$

H4: There is a significant relationship between moral hazard and bank value, which is at the threshold of lending behavior. Set threshold variable: loan concentration.

$$\begin{aligned}\mathrm{Ln}TQ_{it} &= \beta_{1i}\ln LG_{it} + \beta_{2i}\ln RC_{it} + \beta_{3i}\ln MF_{it} + \\ &+ \beta_{4i}\ln EY_{it} + \beta_{5i}\ln DS_{it} + \beta_{6i}\ln MH_{it} + \beta_{7i}\ln FC_{it} + \\ &+ \beta_{8i}\ln DSR_{it} + \beta_{9i}A_{it}\,[\beta_{1i}\ln LG_{it} + \beta_{2i}\ln RC_{it} + \\ &+ \beta_{3i}\ln MF_{it} + \beta_{4i}\ln EY_{it} + \textstyle\sum_{j=1}^{r}\beta_{5i}\ln DS_{it} + \\ &+ \beta_{6i}\ln MH_{it} + \beta_{7i}\ln FC_{it} + \beta_{8i}\ln DSR_{it} + \beta_{9i}A_{it}] \times \\ &\times g(q_{it}^{j};\gamma, c) + \varepsilon_{it}\end{aligned} \quad (5)$$

where: the transition functions, $(q_{it}^{j};\ \gamma_j,\ c_j)$, $j = 1, ..., r$, depending on the slope parameter γ_j and on the location parameter c_j. In particular, the multiple regime model is an obvious alternative in diagnostic tests of no remaining heterogeneity (explanation of all variables – Tab. 2).

3. Research results

Moral hazard is an opportunity cost issue for the banking industry. Inevitably, the operation of the banking industry must consider operating profit and risks. Tab. 3 presents the observations of the lowest (0.020%) and the highest (7.640%) values of the NPL ratio, as well as the standard deviation (0.907).

Tab. 2: Main variables description

Variable		Abbreviation	Description
Dependent variable: Tobin's Q (bank value)		*TQ*	The comparison between the stock market value of the company and the net book value of the bank.
Moral hazard variable	Lending growth rate	*LG*	The loan is the main item used by bank funds and it is the main source of income generated by banks. This study includes changes in short, medium, and long loans.
	Non-performing loan ratios	*NPL*	The NPL ratio is a bank's impaired (non-performing) assets to its total loans.
Bank-specific	Relationship credit ratio	*RC*	Loan transaction object belongs to firm party relations.
	Management fee	*MF*	The proportion of expenses incurred by banks in doing business activities as a percentage of operating income.
	Employee efficiency	*EY*	Employee efficiency is an indicator to calculate the number of business benefits created by each employee, and to reflect the intensity of their employee productivity.
Organizational structure	Director's shareholding ratio	*DS*	Directors' collateralized shares are the pledged shares of directors over the shareholding of directors.
	Manager holding	*MH*	The manager shareholding ratio is the ratio of shares held by corporate managers.
	Friendly corporate ownership	*FC*	A close corporation holds the stock ratio of the bank.
	Director's salary ratio	*DSR*	Remuneration of directors and supervisors as a percentage of the after-tax net profit of the bank.
Lending behavior factors	Loan concentration	*LC*	Loan concentration is an indicator of observing banks' excessive focus on lending in specific industries.
Control variable	Size	*A*	The study uses the total assets as the scale proxy variable.

Source: own

It was found that the NPL ratio was a huge gap between the banking industries. The NPL ratio has always been a critical control line for the competent authorities. It is also a reference for the quality of the bank's NPL ratio. For many banks, it is an essential regulatory point that is regularly reviewed. However, we must also understand that these banks with a high NPL ratio must face the dilemma of having to survive, profit from operations and potential business risks. Observing the minimum (−1.000%) and maximum (4.529%) of the loan growth rate, there is a massive gap between the banking industries. It shows that the loan growth rate is a representative indicator of the growth of the banking industry business, but we believe that there are different requirements and practices for the growth rate of the bank. For example, in the face of banks with a high NPL ratio, although the authorities and the public must propose responsibility for improving the high NPL ratio, the internal

Tab. 3: Descriptive statistics

Variable		Abbreviation	Descriptive statistics		
			Minimum	Maximum	Std. dev.
Dependent variable: Tobin's Q		*TQ*	0.030	0.180	0.024
Moral hazard variable	Lending growth rate	*LG*	−1.000	4.529	0.451
	Non-performing loan ratios	*NPL*	0.020	7.640	0.907
Bank-specific	Relationship credit ratio	*RC*	0.060	5.670	0.943
	Management fee	*MF*	19.300	72.670	10.921
	Employee efficiency	*EY*	−13,579	6,810	1,685.370
Ownership structure	Director's shareholding ratio	*DS*	0.000	100.000	39.952
	Manager holding	*MH*	0.000	2.410	0.423
	Friendly corporate ownership	*FC*	0.000	17.670	2.615
	Director's salary ratio	*DSR*	−17.090	837.260	47.001
Lending behavior	Loan concentration	*LC*	3.406	46.037	5.804
Control variable	Size	*A*	103.000	4,928.000	0.024

Note: Scale unit USD million.

Source: own (based on data provided by the Taiwan Economic Journal database (TEJ, 2018))

executives must also face the plan to increase profit opportunities.

In particular, in the current low-interest-rate environment, the profitability of the banking industry has been severely squeezed. We believe that banks with a high NPL ratio must have more trade-offs between operating profit and moral hazard. The profit from bank operations comes from the high proportion of lending business. In the face of competition from the same industry, it is necessary to take into account both business profit and zero moral hazard. For the banking industry, it seems that there is a trade-off relationship.

In terms of observing the shareholding structure, the directors' shareholding ratio is the largest (100%), the manager's shareholding is the largest (2.410%), and the friendly legal person holds the maximum (17.670%). It indicates that the bank industry may have different forms of functions and objectives for the ownership structure. However, what remains to be seen is the existence pattern between equity structure and moral hazard. In particular, when banks face the choice of operating profit and moral hazard, the function and role of the equity structure is an essential key. In observing the bank's industry lending behavior, bank lending concentration is a vital decision-making method. The minimum (3.406%) and maximum (46.037%) bank lending concentrations show that the bank industry may form the bank's lending strategy in response to external conditions and internal conditions. Therefore, the concentration of lending indirectly reveals the attitude of banks in the face of lending profit and moral hazard when they engage in lending.

Moral hazard variables include lending growth rate and non-performing loan ratios; this study also captures their correlation through changes in these variables. Bank-specific variables include relationship credit ratio, management fees, and employee efficiency; this study also observes the overall impact of these variables on operating value.

In Tab. 4, we find a correlation coefficient between the bank value and the NPL ratio (−0.193), which shows a negative relationship between the NPL ratio and bank value. Conversely, the correlation coefficient between

the loan growth rate and bank value is positive (0.040), indicating that the loan growth rate contributes to the creation of bank value. From the above analysis, we will further explore the different degrees of over-release ratios and the impact of banks' attitudes towards lending growth.

We assume that banks with high NPL ratio ratios have moral hazard behavior. Although the growth rate of lending should have a positive contribution to the value of banks, there may be banks with high NPL ratio ratios. There is a negative relationship between lending growth rate and bank value to the relationship. Therefore, banks with high NPL ratios, even if they are expanding their lending business, may increase their lending business, and most of them may be poor quality lending or lending business with unprofessional decision-making, so there is a high moral hazard problem. In other words, the relationship between moral hazard and bank value is a challenge for banks. Although the banking industry has a higher social responsibility and professional image for the general public than the general industry, it cannot be ignored. Profit must be created, so between competing for banking, it is likely that moral hazard will be the real environment that has to be faced.

We find that the correlation coefficient between the relationship between the transaction of relationship credit ratio and the bank value is (−0.026), which indicates a significant negative relationship. Banks engaged in related party transactions may not be conducive to the development of bank value, but the issues worth discussing may be high. Banks with over-receiving ratios may have a higher probability of having a negative impact on the value of the bank. In addition, the correlation coefficient between employee efficiency and bank value is (0.163), indicating a significant positive relationship. In terms of shareholding structure, the correlation coefficient between bank value and directors' supervisory share is (0.053), the correlation coefficient between bank value and manager's shareholding is (−0.117), and the correlation coefficient between bank value and friendly legal person shareholding is (0.118), both show that the shareholding structure and the bank value have mutual influence. What is more worthy of discussion is whether the bank with moral hazard has different performance and impact.

Finally, we find that the correlation coefficient between the concentration of loans and the value of the bank is (0.198), showing a significant positive relationship. However, we will

Tab. 4: Correlation coefficients

	TQ (1)	*LG* (2)	*NPL* (3)	*RC* (4)	*MF* (5)	*EY* (6)	*DS* (7)	*MH* (8)	*FC* (9)	*DSR* (10)	*LC* (11)	*A* (12)
(1)	1											
(2)	0.040*	1										
(3)	−0.192***	−0.081	1									
(4)	−0.026***	−0.028	0.074	1								
(5)	0.015	−0.026	−0.042	0.021	1							
(6)	0.163***	0.117**	−0.604***	0.029	−0.185***	1						
(7)	0.053*	−0.017	−0.222***	−0.101	−0.020	0.138***	1					
(8)	−0.117**	−0.020	0.217***	0.102	0.150***	−0.170***	−0.526***	1				
(9)	0.118***	0.001	−0.003	0.180***	−0.025	0.0158	−0.144***	−0.048	1			
(10)	−0.051	−0.013	0.048	0.005	0.071	−0.035	−0.101	0.289***	−0.012	1		
(11)	0.198***	0.075*	0.011*	0.360	−0.127***	0.182***	−0.208***	−0.134***	0.062	−0.011	1	
(12)	−0.075	0.002	−0.355***	0.036	−0.330***	0.334***	0.643***	−0.426***	0.099	−0.125*	−0.236***	1

Note: ***, **, and * indicate significance at the 0.01, 0.05, and 0.1 level.

Source: own (based on data provided by the Taiwan Economic Journal database (TEJ, 2018))

further discuss the impact of different levels of lending concentration on bank value and observe the extent to which lending concentration affects moral hazard.

3.1 Panel regression results

In Tab. 5, we use linear regression models and analyze the correlation between bank value and moral hazard, corporate governance, and lending behavior. We find that moral hazard agent variables, including NPL ratio and bank value, have a significant negative relationship (−0.004). In addition, the loan growth ratio has a significant positive correlation (1.312) with bank value. When we capture the cross multiply items of the loan growth ratio and the NPL ratio ratios, we find that the cross multiply variable has a negative relationship with the bank value, which means that when the bank expands the loan growth rate, it can actually enhance the bank value, but must consider the NPL ratio. From the above analysis, we believe that any bank is reluctant to have a high NPL ratio. However, from a realistic perspective, when banks face potential moral hazard and lending gains, they are a dilemma for banks because the moral hazard is the uncertainty after bank lending.

Usually, the bank lending process must have management measures, and the bank has administrative authority for the loan amount to be high or low. Therefore, the lending behavior will likely have to go through the business operators' staff and cross the high-level management to complete the release of the lending behavior. Obviously, the bank's organizational structure, internal factors, and the relevance of the lending strategy to the quality of lending must be discussed.

We find that in terms of bank-specific, relationship transactions (−4.968), management fees (−0.0004), and bank value show a negative relationship. The empirical results show that banks must have professional ways to manage transaction and management expenses. In terms of organizational structure, managers hold shares (0.155), and directors and supervisors hold a significant positive relationship with bank value (9.917). However, the directors' compensation ratio has a significant negative relationship with the bank's value (−9.693). It means that the bank must have a system standard for the directors' remuneration ratio, and it is more important to issue the director's professionalism and give back to the bank's value.

Finally, in terms of bank lending strategies, we find that moderate lending concentration has a significant positive relationship with bank value (0.00061), implying that the concentration of lending needs to be a financial or non-financial analysis of lending objects by bank professionals. In addition, the bank's construction of industrial databases and industry analysis is also an essential professional indicator for banks. On the contrary, we also found that the bank's excessive concentration of loans affected the value of the bank from a positive relationship to a negative correlation (−3.332), and the empirical results support hypothesis *H3*.

These phenomena indicate that banks have the right to choose any type of lending strategy, but we believe that the bank's lending strategy should reveal attitudes about moral hazard. When the bank decides on a lending strategy, it indirectly shows the bank's cognitive attitude toward moral hazards and the goal of lending quality.

Tab. 5: Panel regression analysis – Part 1

Independent variable		Abbreviation	Dependent variable: Tobin Q
Constant		*C*	0.1540*** (0.0410)
Moral hazard	Non-performing loan ratios	*NPL*	−0.0040*** (0.0010)
	Lending growth rate	*LG*	1.3120** (0.6030)
	*LG * NPL*		−0.0020 (0.0050)

Tab. 5: Panel regression analysis – Part 2

Independent variable		Abbreviation	Dependent variable: Tobin Q
Bank-specific	Relationship credit ratio	*RC*	−4.9680 (0.0010)
	Management fee	*MF*	−0.0004*** (0.0001)
	Employee efficiency	*EY*	1.8730** (9.1580)
Organizational structure	Director's shareholding ratio	*DS*	9.9170** (4.7470)
	Manager holding	*MH*	0.1550*** (0.0370)
	Friendly corporate ownership	*FC*	0.0020*** (0.0004)
	Director's salary ratio	*DSR*	−9.6930 (2.5700)
Lending behavior factors	Loan concentration	*DLS*	0.00061** (0.0003)
	Loan concentration	DLS^2	−3.3320* (1.8330)
Control variable	Size	*A*	−0.0091*** (0.0022)
Observations			330
***R*-squared**			0.3160
Adjusted *R*-squared			0.2910

Note: *, **, and *** denote 10, 5, and 1% significance levels, respectively.

Source: own (based on data provided by the Taiwan Economic Journal database (TEJ, 2018))

3.2 Panel threshold regression results

In Tabs. 6–8, we use the transition variable, and the LRT tests support the non-linear relationship between bank value and threshold variables (NPL ratio, NAL ratio and loan concentration). The results show that the LRT test (LRT) supports the non-linear relationship between bank value and moral hazard, organizational structure, and lending behavior under different thresholds.

We next apply a sequence of tests to determine the order m of the logistic function. In practice, it is usually sufficient to consider $m = 1$ or $m = 2$ for the transition function, as these values allow for commonly encountered types of variation in the parameters. The testing results show that the reasonable number of thresholds is $r = 2$ (NPL ratio, and loan concentration), which means that there are two regions, and each region has two regimes.

Tab. 9 shows that the moral hazard is in the bank range of the high NPL ratio. In the high NPL ratio, the loan growth rate has a significant negative relationship with the bank value (−0.0322), which means that the bank is a high moral hazard. In order to enhance the bank's performance pressure, there is a risk-based lending behavior. This study believes that banks will risk high-risk lending behavior, and banks may face pressure on business performance. In particular, the number of bankers has increased in recent years, and in the era of low interest rates, the advantages of the bank's original deposit spreads have disappeared. The situation of the bank industry operating profit compression is serious.

Tab. 6: Test of linearity and testing the number of regimes

Threshold variable	Non-performing loan ratios (*NPL*)		Loan concentration (*LC*)	
	Statistics	*P*-value	Statistics	*P*-value
Wald test (LM)	90.105	0.000*	86.048	0.000*
Fisher test (LMF)	3.812	0.000*	3.578	0.000*
LRT test (LRT)	105.641	0.000*	100.064	0.000*

Note: * denotes significance at the 5% level; LM and pseudo-LRT statistics have a chi-square distribution with MK degrees of freedom, whereas the *F*-statistics have *F*-distribution; LMF is its *F*-version; pseudo-LRT can be computed according to the same definitions by adjusting the number of degrees of freedom.

Source: own

Tab. 7: Test of sequence of homogeneity tests for selecting *m*

Threshold variable	Non-performing loan ratios (*NPL*)		Loan concentration (*LC*)	
H03: B3 = 0	*F*3 = 0.280	0.000*	*F*3 = 0.131	1.000
H02: B2 = 0|B3 = 0	*F*2 = 0.543	0.000*	*F*2 = 0.438	0.994
H01: B1 = 0|B2 = B3 = 0	*F*1 = 2.949	0.000*	*F*1 = 3.048	0.000*

Note: * denotes significance at the 5% level; LM and pseudo-LRT statistics have a chi-square distribution with MK degrees of freedom, whereas the *F*-statistics have *F*-distribution; LMF is its *F*-version; pseudo-LRT can be computed according to the same definitions by adjusting the number of degrees of freedom.

Source: own

Tab. 8: Testing the number of regimes – test of no remaining non-linearity

Threshold variable	Non-performing loan ratios (*NPL*)		Loan concentration (*LC*)	
Wald test (LM)	15.358	0.082	23.609	0.009
Fisher test (LMF)	1.475	0.157	2.074	0.027
LRT test (LRT)	15.735	0.073	24.517	0.006
Value of the threshold	6.009		10.594	

Note: * denotes significance at the 5% level; LM and pseudo-LRT statistics have a chi-square distribution with MK degrees of freedom, whereas the *F*-statistics have *F*-distribution; LMF is its *F*-version; pseudo-LRT can be computed according to the same definitions by adjusting the number of degrees of freedom.

Source: own

Due to competition in the bank loan business, including competition for loan conditions, and competition for services. These banks, which have a high NPL ratio, are facing unfavorable operating conditions because they cannot compete with banks with good image. Still, it is also necessary to face the issue of continuing to operate. Therefore, it is a real problem for banks that are subject to high over-receiving ratios to be subject to moral hazard. The empirical results here support hypothesis *H1*.

Observing the bank-specific factors, we find that the bank-related transaction with a high NPL ratio has a significant negative relationship with the bank value (−0.0322). This indicates that banks with a high NPL ratio may face moral hazards when dealing with related parties. The shareholding ratio of directors and

Tab. 9: Final estimation of PSTR model – non-performing loan ratio (NPL)

Dependent variable: Tobin Q independent variable		Threshold variable: non-performing loan ratios (*NPL*)	
		Low NPL regime	High NPL regime
Moral hazard variable	Lending growth rate (*LG*)	0.3728*** (0.1270)	−0.0322*** (0.1380)
Bank-specific	Relationship credit ratio (*RC*)	0.1070*** (0.0310)	−0.1180*** (0.0350)
	Management fee (*MF*)	0.0020*** (0.0010)	−0.0030*** (0.0020)
	Employee efficiency (*EY*)	−0.0001 (0.0001)	0.0002 (0.0002)
Organizational structure variable	Director's shareholding ratio (*DS*)	0.0012** (0.0008)	−0.0014** (0.0009)
	Manager holding (*MH*)	0.0320*** (0.0220)	−0.0410*** (0.0280)
	Friendly corporate ownership (*FC*)	0.0170*** (0.0100)	−0.0180*** (0.0110)
	Director's salary ratio (*DSR*)	0.0001 (0.0010)	−0.0002 (0.0020)
Control variable	Size (*A*)	−0.0327*** (0.0092)	−0.0066*** (0.0072)
Observations		330	
Estimated slope parameters		−0.417	
Estimated location parameters		6.009	

Note: *, **, and *** denote 10, 5, and 1% significance levels, respectively.

Source: own (based on data provided by the Taiwan Economic Journal database (TEJ, 2018))

supervisors (−0.0014), the shareholding ratio of managers (−0.041), the ratio of directors' compensation (−0.0002), and the shareholding ratio of friendly corporations (−0.018) from the organizational structure are all negatively related to bank value. This means that the management class has invested in the corporate governance mechanism and has not produced management results for the bank's value. The empirical results here support hypothesis *H2*.

From the above analysis, we have profoundly found that banks with high NPL ratio have evidence of moral hazard evidence, the negative impact of the relationship between people's transactions on bank value, and the fact that organizational structure has no management effect on bank value. Banks implying moral hazard may not be a single-oriented problem. These banks are related to holistic issues. Therefore, the way these banks improve is not only to adjust from the loan business behavior but to think of improving the comprehensiveness of management from the management level, internal factors, bank-specific, and organizational structure.

For the banking industry, there are many different strategic considerations for lending, but banks' business performance is the biggest goal. But the way banks choose lending behavior, such as the degree of concentration of different lending, each bank has different strategies. The characteristics of the loan behavior also reveal the bank's attitude towards loans with high moral hazard.

In Tab. 10, we find that in case of banks in the high loan concentration range, NPL ratio have a significant negative relationship with the bank value (−0.0054). However, the loan growth rate has a significant negative relationship with the bank value (−0.0007), indicating that banks with high loan concentration ranges have high moral hazard. We compare banks that are in the low loan concentration range and find that the NPL ratio has a significant negative relationship with the bank value (−0.0054), but the loan growth rate has a significant positive relationship with the bank value (0.0085). The empirical results here support hypothesis *H4*.

In the case of banks with low loan concentration ranges, their lending growth rate has a significant positive contribution to bank value, showing banks in the low loan concentration range have high-quality loan expertise, and it is positive to exclude moral hazard loan attitudes.

Different from the past literature, we capture the possibility of moral hazard from the differences in loan behavior. The empirical results imply that loan behavior is an essential factor in observing whether banks have a moral hazard. Therefore, this study reminds us that when observing the moral hazard of banks, it is recommended to add observations on the differences in loan behaviors to capture the potential risks of bank moral hazard.

In terms of organizational structure, the banks that belong to the high lending concentration range, the manager's shareholding

Tab. 10: Final estimation of PSTR model – loan concentration (LC)

Dependent variable: Tobin Q independent variable		Threshold variable: loan concentration (*LC*)	
		Low LC regime	**High LC regime**
Moral hazard variable	Non-performing loan ratios (*NPL*)	−0.0086*** (0.0013)	−0.0054*** (0.0019)
	Lending growth rate (*LG*)	0.0085*** (0.0014)	−0.0007*** (0.0012)
Bank-specific	Relationship credit ratio (*RC*)	−0.0005 (0.0009)	−0.0013 (0.0013)
	Management fee (*MF*)	−0.0012*** (0.0001)	−0.0005*** (0.0001)
	Employee efficiency (*EY*)	−0.0001* (0.0001)	0.0002*** (0.0001)
Organizational structure variable	Director's shareholding ratio (*DS*)	0.0005*** (0.0001)	−0.0006*** (0.0001)
	Manager holding (*MH*)	0.1149*** (0.0176)	−0.0096*** (0.0174)
	Friendly corporate ownership (*FC*)	0.0011*** (0.0006)	−0.0099*** (0.0026)
	Director's salary ratio (*DSR*)	−0.0011*** (0.0002)	−0.0001*** (0.0001)
Control variable	Size (*A*)	−0.0065*** (0.0041)	−0.0058 (0.0007)
Observations		330	
Estimated slope parameters		539.304	
Estimated location parameters		10.594	

Note: *, **, and *** denote 10, 5, and 1% significance levels, respectively.

Source: own (based on data provided by the Taiwan Economic Journal database (TEJ, 2018))

ratio (−0.0096) and the shareholding ratio of directors and supervisors have a significant negative relationship with the bank value (−0.0099), indicating that the organizational structure of these banks is not effective for the bank value. From the above analysis, we observe that banks with a high lending concentration range, these banks' expansion of loan growth rate is the main goal, but these banks have low standards for lending quality requirements.

Unlike previous literature, we use the empirical results of the non-linear threshold model to find the relationship between moral hazard and bank value under different threshold conditions, considering the NPL ratios and the loan concentration threshold under various conditions. Therefore, compared with past literature, there are indeed differences under different thresholds, and the impact of moral hazard phenomena on business value is captured. In addition, when considering the NPL ratios and loan concentration threshold under various conditions, bank characteristics have different effects on bank value, which helps us re-observe the significance of bank operating characteristics.

This study uses the NPL ratio and loan concentration as thresholds from the non-linear relationship to re-observe the correlation between the NPL ratios and bank value. The threshold value for capturing the NPL ratios is 6.009. We found that it is in the range of high NPL ratios, and most have a negative and significant impact on bank value regardless of bank characteristics, and organizational structure. This study further discussed the non-linear relationship and found a situation similar to previous literature. In other words, banks with high NPL ratios must re-establish their operating conditions to improve their operating constitution.

In addition, this study further explores the impact of lending behavior on the lending growth rate, using lending concentration as the threshold, and the threshold to capture lending concentration is 10.594. Unlike previous literature discussions, this study sets loan concentration as the threshold value and observes the substantial impact of variables such as loan growth rate on bank value. It belongs to the low loan concentration range. We found that the loan growth rate positively impacts bank value. However, in the range of high loan concentration, we found that loan growth rate has a negative and significant impact on bank value and organizational structure variables, including manager shareholding, significant shareholder shareholding, and related enterprise shareholding, all significantly impact the bank value has a negative significant effect.

Conclusions

Taiwan is in an era of low interest rates. The banking industry is facing a competitive business environment. In the past, it has been able to lose its business advantage with high deposit spreads. Because of the need to maintain profitability and risk in the face of low interest rates, it is indeed a challenge for the banking industry.

Although moral hazard is a topic that the banking industry is reluctant to face, the hidden moral hazards do exist. Through empirical analysis, we first capture banks that have high NPL ratios, where the loan growth rate has a negative relationship with the bank value, which means that the moral hazard is present in the banks with high NPL ratios. However, due to a large number of bankers, the market is under competitive pressure. The lending conditions may adopt a relaxed attitude so that the poor quality of lending affects the value of the bank. Secondly, we find that the internal factors, specifically the bank's relationship between the transaction rate and the operating expenses with the bank value, are negatively correlated, indicating that the management capacity of banks with a high NPL ratio needs to be strengthened. Furthermore, we observe that the ownership structure and the bank value show a significant negative relationship, which means that the equity structure fails to play a role in the bank's value. Through the above analysis, we can find that the bank exists with a moral hazard. No matter the internal factors of the bank, the equity structure, and other facets, there is a negative relationship to the bank's value.

We remind banks that there are high NPL ratios, and although it is important to expand the lending business, improving the quality of lending is more important. Although the banking industry's operating environment is competitive, the good business image established in the banking industry and the public is sustainable. Banks are responsible for coaching the industry or lenders to improve or enhance their ability to operate, rather than just

short-term expansion of the lending business so that banks are full of high moral hazard. We also remind the competent authorities that it is more important to master the professional attitude of bank lending habitually than after the NPL ratio event because relevant authorities guiding the bank's quality lending profession is fundamental.

In addition, in terms of the bank's concentration of loans, the results of panel regression analysis show that the concentration of lending has a significant positive relationship with the value of the bank. However, when we further observe that the squared term of the concentration of lending has a significant negative relationship with the bank value, it means that with too much concentration of lending, there will be a reversal of the relationship between bank values.

Second, we have captured banks with high loan concentration. The loan growth rate has a significant negative relationship with the bank's value. Banks that express the excessive concentration of loans have high moral hazard. This phenomenon implies that the bank uses different lending concentrations but indirectly reveals the attitude of the bank's lending quality. Due to the excessive concentration of loans, it is possible that banks and lenders have lost the professional management of lending that they should have. Therefore, bank lending behavior also leads to high moral hazard. Our empirical results support hypotheses *H1–H4*.

Finally, from the economic environment, we are able to recognize the predicament of banking industry operations is getting higher and higher. However, it is important to maintain a professional image of the banking industry. The banking industry should focus on developing more banking products and services, using financial expertise and global trends, developing more business models that can cater to the low interest rate era, and jumping out of traditional financial services and frameworks. For banks that do not have the advantage of operating conditions, it is necessary to conceive the positioning of the business or a new business model. Although financial market competition is a common issue in the banking industry, it is even more important to reduce the loan business, which may generate high moral hazards and change the quality of loans.

Comparing the results of relevant literature in recent years and this article, first of all, moral hazard in the banking industry does exist, consistent with Francis et al. (2019), who found that moral hazard problems exist in the banking industry. This literature also believes that judging from the continuous financial violations or moral hazard problems in the banking industry, it seems that its profitability is higher than the moral hazard, making it easy for the banking industry to take risks and engage in moral hazard behaviors. The banking industry faces fierce competition. In a business environment, engaging in morally hazardous behavior is a challenge.

Secondly, this article believes that organizational structure and bank characteristics may affect the degree of moral hazard. We have also seen that banks with advantages reimagine the thinking of high governance standards and require high-quality loans. We also follow Brandao et al. (2020), who emphasize the importance of banking industry governance. It is believed that professional governance measures can reduce financial market crises. Zheng (2020) found that opacity hurts bank loan growth. Therefore, we believe that governance measures significantly impact the banking industry, especially the occurrence of moral hazard, primarily due to less transparent operations. Banking is prone to happen. This article believes that these considerations are significantly relevant because banks involve organizational structures and bank characteristics.

Furthermore, unlike recent related literature, this article discusses not only the over-lending ratio but also the phenomenon of loan concentration. The main contribution is to remind the banking industry that both over-lending ratio and loan concentration are possible consequences of the banking industry. Lending behavior requires a more detailed capture of potential moral hazard phenomena. Therefore, the banking industry should eliminate the business thinking of short-term profits. Although the banking industry's profits are essential to sustainable development, it is even more worthy for the industry to pay attention to the development of emerging business models. In particular, the banking industry is facing the advent of the ESG era. Through ESG governance measures, risk management and professional governance measures with professional capabilities will be banks' real core development trend, improving the public's image of the banking industry's social responsibility.

The banking industry develops more new financial instruments, develops loan measures and tools suitable for legal persons or the general public, and innovative financial instruments will enable banks to develop more high-yield businesses that will be able to meet the financial needs of more modern society or the flexibility of the loan. In addition, the generation of artificial intelligence has arrived. The management and early warning of risk through professional information systems is the trend of bank development. It also establishes professional system management measures for high moral hazard problems and measures and analyzes moral hazard with intelligent professional systems. Moral hazard management will play a more scientific management benefit. From the perspective of international suggestions, empirical evidence from Taiwan's banking industry shows a correlation between the development of the banking industry and the overly competitive business environment. Therefore, how to transform the role of the competitive environment into healthy competition instead of vicious competition is worthy of reference for other countries. Due to Taiwan's banking industry's excessively competitive business environment, loan concentration has occurred, and fierce competition, such as lending behavior with significant moral hazard, has happened. This article believes creating a competitive banking industry environment is essential. The banking industry should use its business expertise, integrity, and lending targets that align with corporate social responsibility. For example, the lending targets in the banking industry will be selected to support ESG industries.

In terms of sustainable operations in the banking industry, sustainable operation policies and strong corporate governance have a macro impact on enhancing bank operating value. We believe the company has strong corporate governance, professional capabilities, high trust, and other competitiveness, making it the most competitive in the banking industry. Therefore, implementing ESG policies will help enhance the competitiveness of the banking industry, generate more operating value, and improve the centripetal force of the public. In addition, macro banks will not focus on the company's short-term profit factors but will have a high level of thinking on sustainable business policies to follow the breadth of global vision. Finally, this study recommends that future researchers break through the framework of the research period to have a complete research period, continue to explore the comparison of the banking industry before and after the implementation of ESG policies and observe changes in moral hazard from a whole perspective.

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Identification of consumers willing to buy green products – A case study in the Czech Republic

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Abstract: *Green products are one way to protect the environment and eliminate the negative impact of human activity on the environment. However, the expansion of the sale of these products faces many challenges. One of the most significant obstacles is often cited as higher prices. The aim of this paper was to identify consumers willing to buy green products. The primary factors analysed were the social background of consumers, price and the premium for green products. Secondary data in the form of other research on the issue was used to meet the objective. The theoretical aspect of green product purchasing behaviour was supplemented with information from the processing of primary data from a questionnaire survey. The target group was the working-age population with at least a secondary education in the northwest of the Czech Republic. The survey was conducted between May and September 2023 on a sample of 267 respondents. A factor analysis was used in the data analysis to identify the relationships between the factors under study and to reduce the dimensionality of the data, as was segmentation using cluster analysis and classification using decision trees. The results provide information on the green purchasing behaviour of consumers in the study region. Two segments of marketing interest for green product purchasing were identified. One is the segment of ordinary consumers, mostly well-off women with children, who are willing to pay more for green products than other groups of people. The other interesting segment was mostly single women, influenced by opinions on their environment, who do not buy green products regularly and are willing to pay extra for green products, but not a significant amount. The findings of the study may provide useful information for marketers when planning and implementing activities related to green products.*

Keywords: *Green purchasing behaviour, green consumption, factors influencing green purchasing behaviour, social factors, economic factors.*

JEL Classification: *M30, M31, M39.*

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Introduction

Globally, the increasing consumption of goods and services is experiencing rapid growth, which is depleting natural resources and causing significant environmental degradation, a fact that has led to the emergence of the concept of sustainable development, which promotes the reduction of environmental impacts (Omar et al., 2020).

Due to global warming and climate change in particular, in recent years, there has been a steadily increasing interest in environmental issues often related to the depletion of natural resources, air and water pollution, soil erosion as well as climate change occurring globally (Takahashi et al., 2018). According to Har et al. (2011), consumers are interested in activities that can protect the environment. From this point of view, we distinguish two main concepts: green production and green products.

Green production focuses on minimising negative environmental impacts and conserving natural resources through environmentally friendly practices. It encompasses the entire production cycle, starting with raw materials and ending with a finished product (Li et al., 2023).

Green products can be defined as those products that have the least environmental impact, contain ingredients and materials that are environmentally friendly, are recyclable and require less packaging. The purpose of these products is primarily to protect the environment and human health (Gilal et al., 2020). Ciobanu et al. (2022) summarise a green product as an improved version of a conventional product, where this version causes less negative environmental impacts, has a different life cycle, has an environmentally friendly structure and saves energy. In their publication, Dropulić and Krupka (2020) point out that the definition of green products is still ambiguous, as there is no product that does not have any negative impact on the environment at any stage of its life cycle. The authors Goktuna and Hamzaoglu (2023) focus on the purchase of green products in the context of green production, perceiving its benefits for both solving environmental problems and ensuring animal welfare.

The aim of the paper was to identify consumers willing to buy green products by examining the factors influencing their purchase decisions. The selected factors analysed were the social environment of the consumers, the price and the amount of the premium on green products. Fulfilling the objective of the thesis will provide information about the target group buying green products for final consumption, which is useful for companies in order to prepare the most eye-catching marketing offers to increase purchasing of green products.

1. Theoretical background

Society needs to accept that it is important to pay more attention to the issue of green consumption and to lead an environmentally responsible lifestyle (Berenguer, 2010). Promoting green purchasing behaviour is one of the ways in which the negative environmental impacts of products can be reduced in order to achieve sustainability (Casalegno et al., 2022; Sadiq et al., 2022). It is crucial to promote sustainable agricultural and consumer practices among households by buying wisely from companies that themselves focus on sustainability (Iannuzzi, 2017; Kamalanon et al., 2022). A number of studies have addressed the issue of green purchasing behaviour along with the analysis of the factors that influence a consumer's decision to purchase green products (e.g., Dutta et al., 2022; Haffar et al., 2020; Jing et al., 2022; Liobikienė & Bernatonienė, 2017). Key factors that influence the decision to purchase green products include consumer demographic characteristics such as age, gender, income, education and marital status (Goktuna & Hamzaoglu, 2023; Vehapi & Dolićanin, 2016). In addition, social factors such as the influence of close persons such as friends and family (Khor & Mah, 2020; Kumar & Shanthini, 2020), as well as cultural and religious attitudes play a role (Addisu, 2018). Important economic factors that influence the purchase of green products include their price and any surcharges or price premiums associated with these products (Ciobanu et al., 2022; Vapa-Tankosic et al., 2018; Wang et al., 2019).

However, the literature still lacks a comprehensive picture of green consumer behaviour, especially if the influence of friends and family is a stronger factor in relation to green purchasing than the price of these products. Therefore, for the purposes of this paper, social and economic factors will be primarily considered.

1.1 Social factors

Consumer habits and consumption patterns are largely influenced by the attitudes of people who are considered important to consumers,

such as relatives, friends, co-workers and colleagues (Hynes & Wilson, 2016; Setiawan et al., 2021). Maichum et al. (2016), Ahmed et al. (2019), and Hamzah and Tanwir (2021) point out that social interests (family, friends, retailers or other people who share the experience of green products) are also important to a consumers' decision to buy green products. According to Vehapi and Dolicanin (2016), family members and friends are among the main sources from which consumers get information about green products. Also, Suki (2019) investigated the influence of the environment on consumer purchasing behaviour and found that friends and peers have a significant influence. Khor and Mah (2020) come to the same conclusion, finding that consumers are influenced by social norms in the form of expectations from friends, peers or family when purchasing green products. Addisu (2018) presents the finding that social factors in the form of culture and religion do not have a significant influence on the consumption of green products, while factors such as the aforementioned influence of friends or family members do influence the consumption of green products. Authors Kumar and Shanthini (2020) show a significant relationship between peer appeal and the purchase of green products. According to Goktuna and Hamzaoglu (2023), factors such as family and friends have a positive but insignificant influence on the consumption of green food products. Ciobanu et al. (2022) did not confirm the influence of social factors (in the form of friends' recommendations and social trends) in their study.

1.2 Economic factors

In order to understand the issues surrounding consumers' willingness to pay a higher price for green products, it is necessary to examine the factors that influence price sensitivity (Sheth, 2021). The term "willingness to pay a premium for green products" can be defined as the highest amount a consumer is willing to pay for a particular product (Katt & Meixner, 2020). The high prices of green products may represent a barrier that prevents consumers from purchasing these products.

According to a number of studies, price has a significant impact on consumers' evaluation of product alternatives, which can influence their intention to make a purchase decision (Moser, 2016). Low price sensitivity positively influences green purchasing behaviour (Eze & Ndubisi, 2013), while high price sensitivity can negatively influence consumer purchasing behaviour. High prices negatively affect the consumer's intention to purchase a green product (Joshi & Rahman, 2015; Prakash et al., 2019). Prices are set by the producers of green products who are concerned with profit maximisation, and in order to make strategic pricing decisions on consumers, it is necessary to understand what elements can influence the so-called personal acceptable price range for green products (Dominique-Ferreira & Antunes, 2019; Molinillo et al., 2020).

Khor and Mah (2020), Ciobanu et al. (2022), and de Leeuw et al. (2015) point out that the price of green products has a significant impact on consumers' willingness to purchase these products. However, Omar et al. (2020) point out that price is one of the indicators that helps consumers to distinguish green products from conventional ones. This issue has been addressed in the Czech Republic by Zámková et al. (2021), who point out that price, which used to be the most important factor of all, has taken a back seat in the Czech Republic as consumers have started to favour higher quality and appreciate the health benefits of green products.

Vehapi and Dolicanin (2016) and Zhao et al. (2018) mention in their research that most consumers are willing to pay a price premium for green products and argue that green consumers are less price sensitive compared to non-green consumers. On the other hand, Addisu (2018) states that consumers are not willing to pay a premium for green products and are very price sensitive to the products in question.

Wang et al. (2019) argue that consumers who have attained a higher educational attainment and higher income are willing to pay a higher premium for green products. According to the authors, household size also influences the premium people are willing to pay for green products, with small (up to 4 people) and medium (4–6 people) households willing to pay a price premium of 10–20% (Vapa-Tankosic et al., 2018).

The result of research by Gomes et al. (2023) showed that Generation Z is willing to pay a premium for green products because of environmental concerns, estimates of a green future and perceptions of green benefits.

2. Research methodology

This study examines the purchase of green products and explores selected factors that

influence consumer purchasing decisions. The present study examines selected factors that influence consumers in purchasing green products. Data collection from primary and secondary sources was used to meet the objective of the study. Secondary data was mainly obtained from scientific and professional publications. This data was intended to reflect current trends in the field. Primary data collection was used to investigate factors influencing consumption decisions in order to identify consumers willing to purchase green products. Primary data was collected through a questionnaire survey. The research focused on analysing people's attitudes towards the environment and the purchase of green products.

To achieve the research objective, two research questions were established based on the studies reviewed. The research questions are:

RQ1: Who is the typical consumer who is willing to buy green products?

RQ2: What are the effects of the selected factors (social and economic) on purchasing behaviour?

Twenty-five closed questions were formulated based on the purchasing behaviour of consumers of green products. In 19 questions, scaling was used to find out the degree of respondents' perception of the desired state. The respondents were required to express their opinions about the phenomenon being studied by recording a particular position on the scale. A five-point Likert scale (1 = strongly disagree, 5 = strongly agree) was used in the questionnaire. The questionnaire also included questions on the general characteristics of the respondents and their households, given that buyer purchasing behaviour is generally influenced by education, age, gender, job position and household financial situation.

The target group consisted of the population of the geographical areas of the northwest of the Czech Republic with at least a secondary education, of working age, i.e., in the age category 19–65 years, regardless of whether they currently buy green products or not. The northwest region is characterised by the lowest GDP per capita in the Czech Republic (Czech Statistical office, 2024). The low GDP in the region influences the purchasing behaviour of the population, while the high price of green products can be a barrier for them. People with limited financial resources often prefer cheaper alternatives, making it difficult to switch to sustainable and green products. The reason for obtaining data at a local level was increased feasibility in the currency of the information enabling adaptation to the requirements of a specific area. On the other hand, it can be demonstrated that information from a specific territory can also inspire other regions.

Prior to the start of the questionnaire survey, a pilot test was carried out to verify the comprehensibility of the questionnaire for all respondents and to detect any errors in the questionnaire. Shopping malls and supermarkets, universities and workplaces were used to recruit respondents. The empirical research considered various aspects of the potential of individual respondents as well as the general characteristics of their households. The survey was conducted through face-to-face interviews with the respondents and online questioning via QR code from May to September 2023.

A total of 267 respondents took part in the survey, of which 28% were male, 71% were female and 1% of respondents indicated "other" as their gender. A total of 59% of the respondents were single, 33% indicated married as their marital status and 7% of the survey respondents were divorced or widowed. For age distribution, the largest proportion of people was between the ages of 18 and 30. The survey involved respondents with different levels of completed education, with the largest proportion of respondents having successfully completed secondary education with a high school diploma (47%), while 26% of the respondents had achieved a bachelor's degree, 19% a master's degree, 5% had a higher vocational education and only 3% of the respondents had managed to obtain a doctoral degree at university. The largest proportion of respondents was employed (65%), 22% reported student status as their main economic status, and several respondents were on maternity or parental leave, self-employed, retired or on disability pension (12% in total). The groups of the unemployed and those who are housewives or caring for a child or other person were not represented in the survey.

The largest share of households has an income above EUR 32,000 (19%), while only 4% of respondents reported that their household income is below EUR 800. When asked to rate their financial situation, 66% of respondents

said they rated their financial situation as average; 18% rated their situation as above average and 16% below average.

38% of respondents live in a household of 2 persons, 27% of respondents live in a household of 3 persons, 19% of respondents live in a household with 4 persons, 5% of respondents live in households with 5 or more persons and 10% of respondents said they live alone.

The primary data obtained was further statistically processed using factor analysis, clustering and decision tree methods. Factor analysis is used to solve the problem of dimensionality reduction of data. It attempts to express the original variables in terms of latent variables that cannot be measured directly but may have some substantive interpretation. The aim is to simplify the original system of variables and at the same time to find out the structure of their dependencies.

Cluster analysis deals with the similarity of data objects. It deals with dividing a set of objects into several unspecified groups (clusters) so that objects within each cluster are as similar as possible, while objects from different clusters are as similar as possible.

A very common method of data representation used in data models are various types of decision trees. Decision trees are structures that recursively partition the data being studied according to certain decision criteria. While the root of the tree typically represents the entire sample set, the internal nodes of the tree represent subsets of the sample set. In the leaves of the tree, we can read the values of the variable being explained in addition to other information.

A decision tree is usually created recursively by dividing the space of predictor values (explanatory, independent variables). A large number of algorithms have been proposed for creating decision trees. The most commonly used are CART, ID3, C4.5, AID, CHAID and QUEST and their variants. In our analysis, we used the CRT algorithm implemented in the SPSS statistical system environment (Hlaváček et al., 2015).

3. Results and discussion

3.1 Results

As part of the evaluation of research question 1 (*RQ1*), consumers were segmented in terms of the influence of social and economic

Tab. 1: Factors influencing the purchase of green products – Part 1

Opinion questions	Components			
	1	2	3	4
I like to go on trips to the countryside, for example to the woods or fields.	0.138	0.015	0.680	0.179
People seriously abuse the environment.	0.051	0.300	0.717	−0.154
Whenever possible, I try to conserve natural resources.	0.240	0.064	0.766	0.295
It makes me sad to see forests being cut down for agriculture.	0.125	0.226	0.759	−0.078
I take an active interest in the environment.	0.166	0.278	0.651	0.324
Climate change also threatens livelihoods in the country.	0.087	0.442	0.655	−0.198
I think buying green products is a good idea.	0.359	0.548	0.498	−0.106
Most of the people I consider important think that I should buy green products when making purchases.	0.848	0.209	0.260	−0.115
Most of the people I consider important would like me to buy green products when making purchases.	0.891	0.090	0.300	0.006
People whose opinion I value would like me to buy green products.	0.835	0.175	0.298	0.086
The positive opinion of a close friend influences me to buy green products.	0.629	0.455	0.143	0.005
Green products are commonly available in the stores where I usually shop.	0.091	0.180	0.095	0.824

Tab. 1: Factors influencing the purchase of green products – Part 2

Opinion questions	Components			
	1	2	3	4
I will consider switching to green products for environmental reasons.	0.305	0.772	0.316	0.074
I plan to spend more money on a green product than on a conventional product.	0.362	0.766	0.171	0.232
I definitely want to buy green products in the near future.	0.316	0.789	0.354	0.082
My friends buy green products.	0.593	0.461	−0.005	0.275
My family buys green products.	0.652	0.429	0.028	0.221
I buy green products because my friends and colleagues also buy green products.	0.682	0.384	−0.030	0.167
Green products are commonly available in the stores where I usually shop.	0.295	0.728	0.339	0.179

Note: The individual components are differentiated by shades of grey (the first – consumer influence; the second – the reasons for purchasing green products; the third – opinion on the environment; the fourth – the availability of green products).

Source: own

factors on the purchase of green products. The variables obtained from the opinion questions in the questionnaire showed a strong correlation with each other, so factor analysis was used in the preprocessing step (Tab. 1). The result was four components. In Tab. 1, the individual components are differentiated by shades of grey. The first represented consumer influence, the second the reasons for purchasing green products, the third opinion on the environment and the fourth the availability of green products.

Tab. 2: Sociodemographic and opinion characteristics

	Sociodemographic characteristics	Opinion characteristics
1st cluster	Well-off women not living alone with at least a secondary education and at least two non-earners (mostly minor children) living in the household	▪ Buy green products because they care about the environment ▪ Mostly willing to pay a higher price and pay extra for green products
2nd cluster	Single women under 30 years of age living alone with either a high school diploma or a bachelor's degree	▪ Do not buy green products for "moral" reasons ▪ Buy because they care about the opinions of others (whether family or friends, or people they respect) ▪ Willing to pay a higher price for green products ▪ Mostly, but they're not willing to pay extra
3rd cluster	Employed married men aged 31–50 with at least a master's degree, high income living alone or in a complete family (2+2)	▪ Do not buy green products for "moral" reasons, but neither do they care about the opinions of others (whether family or friends or people they respect) ▪ Not willing to pay extra

Source: own

Subsequently, a cluster analysis was performed using a two-stage method. The input variables for the analysis were the factors emerging from the factor analysis. Classification methods were used to interpret the clusters more accurately. The interpretation was done from two aspects corresponding to two parts of the questionnaire, namely soc-dem characteristics and also opinion characteristics. The results are summarised in Tab. 2.

Cluster 1, which consists of women with at least a secondary education who are in a partnered relationship and have at least two children living in the household, were found to be existing regular green shopping customers. These people prefer to buy green products and are willing to pay a higher price. These consumers are influenced by customer retention tools (e.g., loyalty reward schemes, provision of quality customer service and problem solving) in terms of marketing activities.

Cluster 2 is predominantly single women. This group consists of people who are not opposed to green shopping and yet are influenced by views in their surroundings. This group represents an interesting segment of potential customers of green products from a marketing point of view. In terms of marketing activities, these consumers are influenced by the tools used to gain a loyal customer base. These include, e.g., influencer marketing, and emailing.

Cluster 3 consumers said that they do not buy green products either out of conviction or because they are not influenced at all by their family or friends and, thus are not willing to pay a higher price for these products. From a marketing point of view, the third cluster is not a viable customer base for buying green products in the short term. These are mainly consumers who are not very influential and do not prefer to buy green products.

A clustered comparison of the degree of willingness to buy green products and pay a premium price is visible in the box plots in Fig. 1.

The second research question of the data analysis (*RQ2*) examined the relationship between social and selected economic factors (price and price premiums) on the purchase of green products. To evaluate this research question, a decision tree method was used, specifically a classification tree constructed using the CRT algorithm. To construct the decision tree, "I buy green products because I care about the environment" (values: up to 5%, 5–10%, above 10%) was selected as the variable explained, and social factors were selected as explanatory variables observed in the questionnaire survey.

In the text contained in the rectangles of each node of the decision tree (Fig. 2), the percentage of people willing to pay a given level of surcharge can be seen. The text below the nodes lists the variables according to which the algorithm evaluated the split as the most efficient. Based on the classification tree

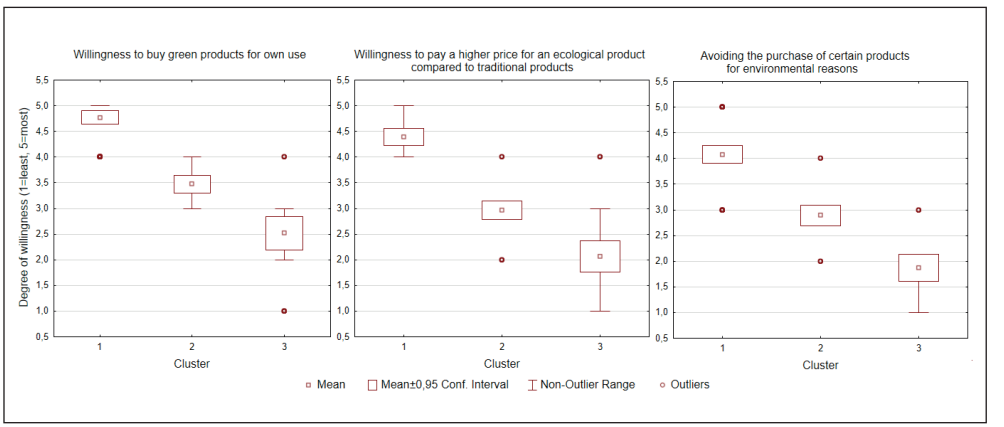

Fig. 1: Cluster comparison

Source: own

developed, it can be concluded that people who want to buy green products for their own use are mostly willing to pay a 10% premium for green products, are influenced by the positive opinion of a close friend, and buy green products because they care about the environment. People who care about the environment, but are not influenced by the positive opinion of close friends when buying green products, or people who buy green products not because they care about the environment, but because of the positive opinion of close friends, are mostly willing to pay a premium of 5–10%. People who do not care about the environment, nor are influenced by the positive opinion of close friends and do not consider buying green products a good idea, are those who will pay at most up to 5% extra for green products.

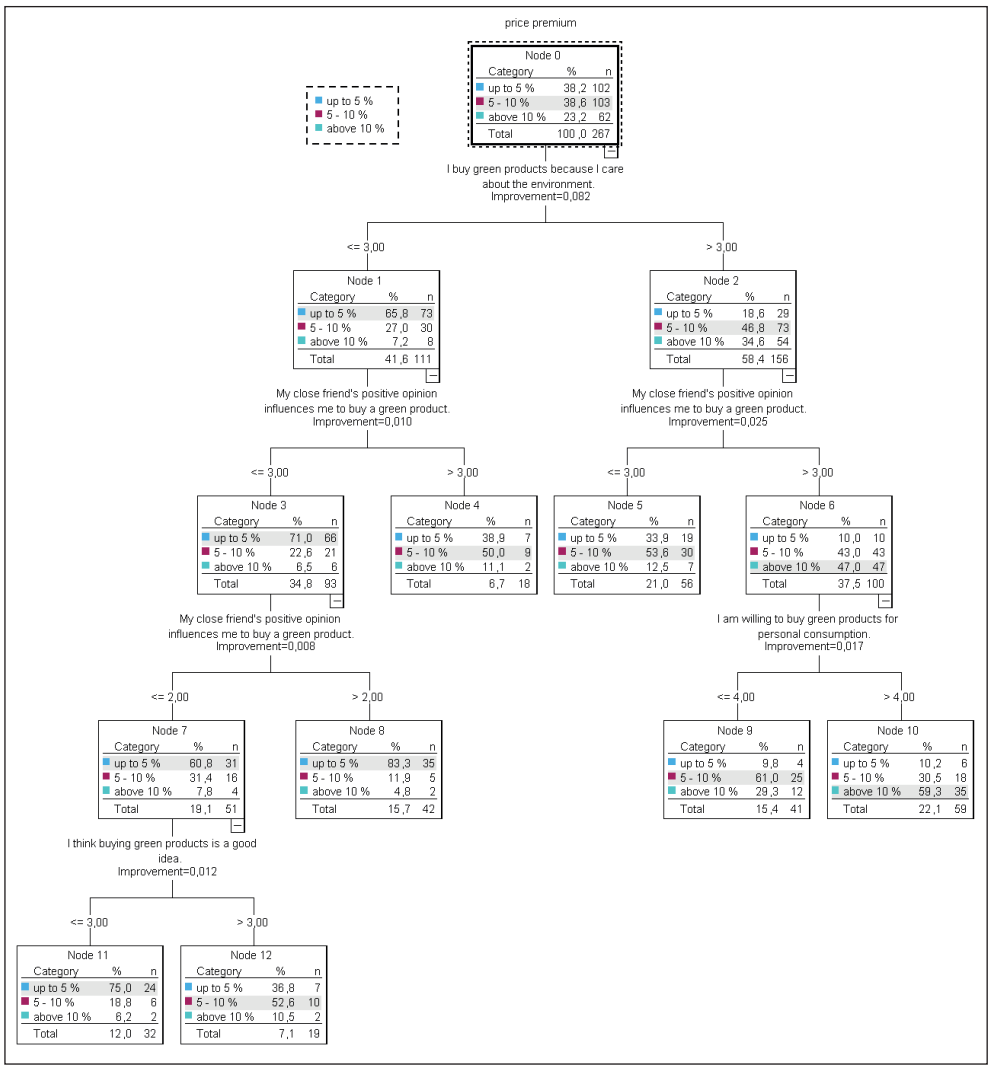

Fig. 2: Decision tree

Source: own

The results of both research questions show that consumers' willingness to buy and pay a higher price for green products is strongly influenced by the opinions of family and friends. In particular, women with at least a secondary education who are actively interested in environmental protection are more likely to prefer buying green products.

3.2 Discussion

In the Czech Republic, the market for green products continues to grow and Czech consumers are gaining a positive attitude towards buying green products; in 2020, the average per capita consumption of green products in the Czech Republic was EUR 21, while in Germany and Austria it was EUR 180 and EUR 254, respectively (Zámková et al., 2021).

According to the results of our study, the price of green products still has a significant influence on purchasing decisions. People are still deciding whether to buy these products rather than "normal" products with a lower price. In our research, this may also be due to the fact that the region studied is one of the regions with the lowest purchasing power (Czech Statistical office, 2024). The fact that the price of green products is an important factor is also confirmed by the studies of Ciobanu et al. (2022) and Khor and Mah (2020). Increasingly, however, other factors besides price as an influencing factor on the purchase of green products are entering into this process (Drupolić & Krupka, 2020; Zámková et al., 2021). One such factor is concern for the environment. People who care about the environment are more considerate towards it and adapt their purchasing behaviour to it (Addisu, 2018). This finding was confirmed by the results of our study. Another factor that still significantly influences the purchase of green products is the influence of family and friends.

The study's research found that people who see their neighbourhood investing in green products are more likely to buy them and are willing to pay more for them, suggesting that the social environment has a significant influence on green purchasing behaviour. The research results show that the opinion of people in a consumer's social environment has a significant influence on their willingness to buy green products.

The findings regarding the social environment of the consumer are consistent with the findings of studies by several other authors, such as Alzubaidi et al.(2021), Budovska et al. (2020), Hamzah and Tanwir (2021), and Kim and Seock (2019). On the other hand, authors Ciobanu et al. (2022) and Goktuna and Hamzaoglu (2023) present opposing conclusions.

From the information found regarding the social environment, it can be concluded that the social environment has an influence on green purchasing behaviour. When verifying the given facts, it was found that when considering the influence of the social environment on the consumer's willingness to buy green products, to pay a higher price for these products and the consumer's intention to buy these products in the near future, the influence of all the given factors is significant. However, the most important variable for consumers is the variable when taking into account the future. This implies that people are aware that they should buy green products and are aware of their benefits and positive consequences.

Vehapi and Dolicanin (2016) state that family members and friends are among the main sources from which consumers get information about green products. Furthermore, these authors, along with Vapa-Tankosić et al. (2018), report that typical consumers are married women or with children with a good financial situation in the household, Goktuna and Hamzaoglu (2023). These findings are consistent with the findings of our research.

Important people, whether influencers or marketing experts, should be aware of this finding. Consumers in the field are following the "if they are doing it, I should probably start doing it" formula. In the context of social media, social factors are major influences on purchase intention and behaviour (Ahmad & Zhang, 2020).

Our study focuses on consumers' purchasing behaviour in terms of green products. In the future, the research could be extended to a deeper analysis of the relationship between green production and green products.

In further research, it would be advisable to expand the sample of respondents to verify the results that were inconclusive. It would also be beneficial to conduct research in cohesion regions where GDP is higher than in our study region. The work focuses on people over 18 years of age with at least a secondary education, and therefore it could be recommended to include people with less education

in the next survey. In addition, future research should broaden the range of factors influencing green purchasing behaviour to better understand what motivates consumers to choose green products.

Conclusions

In recent years, due to global warming and climate change, there has been a steady increase in interest in environmental issues, often linked to the depletion of natural resources, air and water pollution, soil erosion, as well as climate change that has occurred globally. Pollution increases the burden of disease, reduces life expectancy and also reduces the overall quality of life in a country (Har et al., 2011). Addisu (2018) states that consumers are now more environmentally conscious and are also adapting their purchasing behaviour to the environment. It is green products that cause less pollution and contribute to the conservation of natural resources; compared to conventional products, green products are less harmful to human health and the environment, both when evaluating the content of the product itself or its packaging (Ciobanu et al., 2022).

Based on the information gathered, several recommendations can be made for organisations working on green consumption and raising awareness of the importance of green products. The social environment of consumers (in the form of family, friends and other close or important people) plays an important role in the purchase of green products. The more green products that are purchased by people in the consumer's environment, the more likely the consumer is to be willing to purchase the products. In the same way, a consumer's environment influences their willingness to pay higher prices for green products compared to conventional products, and also influences their decisions on future purchases of these products. Given the above information, education of the population is of great importance. In activities aimed at educating consumers about green products or activities aimed at selling these products themselves, it may be advisable to use the social environment of the consumers, e.g., in the form of an influencer campaign or a UGC (user generated content) campaign.

The research also identified socio-demographic variables that influence the purchase of green products. These factors included household size, which is the most important of the factors studied among consumers. The second most important factor is gender, i.e., women are more likely to buy green products. Another factor is economic status, with students and women on maternity or parental leave buying green products. It is therefore advisable to target these consumer groups in the marketing activities of the operators concerned. These insights can be used by business actors in the field to plan and implement their marketing and sales activities (Akram et al. 2024; Lavuri, 2022).

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Cybersecurity management system of large enterprises: Probabilistic behavioural model

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Abstract: *This article presents an in-depth examination of the behaviours of large enterprises in managing information security, aiming to develop a model that illustrates the relationships between various cybersecurity variables. Conducted between 2022 and the first half of 2023, the study involved 52 significant organizations in the Czech Republic, offering insights applicable across the European Union. Amidst rising cyber threats, the research evaluates the current cybersecurity landscape within commercial and public institutions, analysing vulnerabilities, defence strategies, and compliance across different sectors. Utilizing interviews with security and IT managers, the study employs frameworks and methodologies including the Center for Internet Security controls and Bloom's taxonomy, to propose a probabilistic model that clarifies the marginal and conditional probabilities of cybersecurity variables. This model aims to support EU regulatory bodies and organizations specializing in cybersecurity services and training. Additionally, the study explores the impact of top management's cybersecurity education on organizational security levels and the economic aspects of information security management. Despite limitations related to sample size and potential respondent bias, this research contributes to the cybersecurity discourse by offering a comprehensive model that facilitates understanding of the complex interplay of factors affecting information security management in large organizations.*

Keywords: *Cyber security, security awareness, security self-assessment, cybersecurity posture, mutual information, probability distribution.*

JEL Classification: *O3.*

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Introduction

The primary objective of this article is to evaluate the behaviour of large enterprises in the domain of information security management and, based on the information gathered, to develop a model reflecting the relationships between the studied variables. The secondary objectives include an analysis of the state of cybersecurity in commercial organizations and public institutions, with a breakdown into individual sectors. The research was conducted during the year 2022 and the first half of 2023, involving 52 significant organizations in the Czech Republic. However, the findings are applicable to most European Union countries.

In the ever-evolving digital age, cybersecurity stands as a critical pillar in the operational integrity and resilience of modern organizations. According to a report by Sophos (2023), the frequency and complexity of cyber-attacks have been increasing, underscoring a pressing need for robust cybersecurity measures. One of the paramount challenges in cybersecurity is the complexity of modern IT infrastructures, which are often expansive and interconnected, making them more vulnerable to attacks.

Human factors, including employee behaviour, add another layer of complexity. National Cyber and Information Security Agency (2023) highlights that inadvertent employee errors or deliberate actions can significantly compromise an organization's cybersecurity. Furthermore, navigating the legal and regulatory landscape, such as compliance with the General Data Protection Regulation (European Parliament and the Council, 2016b) and the Act on cybersecurity 181/2014 Coll. (National Cyber and Information Security Agency, 2014), adds to the complexity of cybersecurity management.

The main results of this article are supported by data collected during the interviews with security and IT managers. However, we start by examining the current state of knowledge in the researched area, particularly concerning the legal framework in cybersecurity. In addition, we will briefly focus on the current obligations and challenges faced by managers responsible for security within an organization. We will also touch upon some tools that can be utilized in managing cybersecurity in an organization. In the next part of the article, we will guide the reader through the techniques we have decided to use for data collection in our research. The ethical aspect of the research, which was crucial for the effective collection of relevant data considering the studied area, cannot be overlooked. In the following part of the article, we will present the used analytical procedures based on information theory and probability theory. The outputs, conclusions, discussions, and recommendations are then interpreted in the final part of the paper.

This work is based on unique and also very sensitive data, the collection of which was time-consuming. The techniques and procedures used to calculate the model are known from other fields, however, their application to the field of cyber security is an innovative approach for this area.

1. Theoretical background

The role of a manager responsible for the state of cyber security in an organization, typically a chief information security officer (CISO), is currently challenging. On the one hand, the risk associated with dealing with cyber incidents is constantly growing, and the demands for ensuring adequate protection are increasing. However, on the other hand, the resources that would fulfill the security requirements are limited. The main task of the CISO is to ensure the effective protection of the organization against cyberspace threats, however, the necessary resources are usually approved at the level of top management or owners of the organization. However, the willingness of stakeholders to invest in cyber security is influenced by several factors, including their subjective approach to risk. Švadlenka (2021) already pointed out the fact that support from top management or organization owners in the application of cyber security is one of the factors that influence the amount of resources released to this area, and therefore also the overall level of cyber security of the company.

1.1 Security legislation

In the Czech Republic, cyber security is regulated by the Act on cybersecurity, which is managed by the National Office for Cyber and Information Security (Doucek et al., 2019). To ensure information security at the required level, especially in the area of providing critical services for the company, in 2014, the legislative framework defined by Act No. 181/2014 Coll. on cybersecurity and its implementation documentation (National Cyber and Information Security Agency, 2014) was adopted in the Czech Republic. According to this standard, regulated entities have a number of obligations to implement technical and organizational measures, including the necessary security documentation. The development of legislation in the field of cyber security at the international level has not been left behind either. In 2016, Directive 2016/1148, the so-called NIS (European Parliament and the Council, 2016a), entered into force on measures to ensure a high level of security of networks and information systems in the European Union, which stipulated that the member states should bring their national legislation into line with this standard at the latest. As part of the harmonization of European law, Directive 2016/1148 was transposed into the Czech Act on cybersecurity in 2017, which undoubtedly brought new requirements for the organizations concerned. In 2016, with effect from May 25, 2018, Regulation 2016/679 (European Parliament and the Council, 2016b) on the protection of natural persons in connection with the processing of personal data and on the free movement of such data entered into force, which requires the application of many other measures by entities subject to this

standard. Obligations arising from the aforementioned legislative measures are controlled by the relevant state authorities, and non-compliance with the standard may be the cause of a sanction. The latest addition to the field of legislative measures is Directive 2022/2555 (European Parliament and the Council, 2022) on measures to ensure a high standard level of cyber security in the European Union, the so-called NIS2 Directive, which was published in the Official Journal of the European Union on December 27, 2022.

1.2 Security self-assessment

Cybersecurity management in an organization is associated with a process of continuous improvement. However, if we want to improve the sub-components of security, it is necessary to measure them over time and continuously check results (International Organization for Standardization, 2022). Risk analysis is a fundamental tool for working with risks for regulated entities according to the Act on cybersecurity 181/2014 Coll. (National Cyber and Information Security Agency, 2014). However, its implementation and maintenance in the organization's environment require specific knowledge and experience or considerable financial resources for outsourcing these services. However, organizations outside of regulation often cannot or do not want to afford this. This absence results from intuitive security management, which in larger organizations with a complex IT system leads to inefficient cyber security management. An alternative approach for managing Security in an organization can be security self-assessment. Security self-assessment is an essential process for organizations striving to maintain adequate cyber security. By conducting a self-assessment, organizations can gain a comprehensive understanding of their security posture, identify potential vulnerabilities, and prioritize their efforts to address them. In addition, security self-assessments can help organizations meet the regulatory requirements and standards outlined in the previous chapter.

To achieve thorough and consistent assessments, organizations should employ a systematic approach that incorporates the use of established frameworks and standards. Some of the most commonly used frameworks include the NIST Cybersecurity Framework (National Institute of Standards and Technology, 2023), ISO/IEC 27001 (International Organization for Standardization, 2022), the Cyber Security Evaluation Tool developed by Cybersecurity & Infrastructure Security Agency (2024), and CIS controls (Center for Internet Security, 2022). These frameworks provide a structured methodology for assessment and help ensure that all relevant areas are covered. Utilizing these frameworks enables organizations to systematically identify vulnerabilities, assess risks, and implement appropriate control mechanisms. For instance, the NIST Cybersecurity Framework focuses on five key areas: identify, protect, detect, respond, and recover. These areas cover the entire security management lifecycle and assist organizations in comprehensively evaluating their security posture (Scarfone et al., 2008).

The CIS critical security controls are a set of 18 best practices that organizations can use to improve their cybersecurity posture. These controls are organized into three categories: basic, foundational, and organizational. The basic controls are the most critical, and failure to implement them can result in the most significant security risks. The foundational controls provide additional protections, while the organizational controls help ensure that the security measures are appropriately integrated into the organization's overall structure and culture. The CIS controls cover a range of security measures, including hardware and software security, network security, access control, and incident response. They are designed to be flexible and adaptable to different organizations' needs and resources. CIS controls are an essential tool for organizations to protect their digital assets from cyber threats. With the increasing frequency and sophistication of cyber-attacks, implementing these controls can help reduce the risk of a security breach and minimize the damage if one occurs. CIS controls are designed to apply to organizations of all sizes and industries, making them a valuable resource for businesses, government agencies, and non-profit organizations (Center for Internet Security, 2022).

1.3 Security awareness of top managers and user experience

Security awareness is critical to ensuring the protection of an organization's information assets. While many factors contribute to an organization's overall security posture, the awareness and actions of senior management can

have a significant impact. Senior management plays a crucial role in setting the tone for an organization's security culture. Their attitudes and actions toward security can significantly impact the rest of the organization. If top management prioritizes security, the rest of the organization is more likely to follow suit. Studies have shown that a lack of security awareness among top management can lead to a higher risk of security breaches (Kajava et al., 2007).

However, according to (Švadlenka, 2022), the top manager in the organization performs two different roles from the point of view of security. The first is as a regular user of the organization's ICT services with the risks described above. At the same time, however, it significantly affects the amount of resources flowing into the organization's security measures. For this reason, the information security management system, according to the ISO standard (International Organization for Standardization, 2022), forces top management's involvement in the implementation process. Likewise, Decree No. 82/2018 Coll. (National Cyber and Information Security Agency, 2018) on Security Measures requires the participation of a senior manager (or a person authorized by him) in the meetings of the organization's Cyber Security Committee. However, current legislation no longer establishes any other specific requirements for top management education. The new NIS2 directive already mentions this obligation in Article 20: "Member states shall ensure that the members of the management bodies of essential and important entities are required to follow the training, and shall encourage essential and important entities to offer similar training to their employees regularly, so that they gain sufficient knowledge and skills to enable them to identify risks and assess cybersecurity risk-management practices and their impact on the services provided by the entity" (European Parliament and the Council, 2022). However, the question is, in what form will this provision be reflected in the national legislation? One of the possible approaches to monitor and evaluate results in the area of awareness is Bloom's taxonomy (Armstrong, 2010).

Following part of the article introduces the problematics of the intersection of user experience and cybersecurity measures, highlighting the challenges and solutions in balancing security requirements with user convenience. It underscores the significance of user-centric approaches in cybersecurity to enhance both protection and user satisfaction. In the digital era, cybersecurity is paramount for safeguarding data and ensuring privacy. However, stringent security measures often impede user experience, leading to resistance or non-compliance among users. User experience plays a pivotal role in the effectiveness of cybersecurity measures. A study by NIST (National Institute of Standards and Technology) emphasizes that user-friendly security solutions are more likely to be adopted and adhered to by end-users (Grassi et al., 2017). This is echoed by Acquisti et al. (2018), who argue that the complexity of security mechanisms often leads to user frustration and, consequently, weaker security adherence. The primary challenge lies in designing cybersecurity measures that are both secure and user-friendly. Renaud and Zimmermann (2020) highlight that overly complex passwords and frequent authentication requests can lead to "security fatigue."

2. Research methodology

2.1 Data description

To reach the objectives, set out in the introduction, it was necessary to use the processes of conceptualization and operationalization to correctly project the observed phenomena into measurable data. The next task was to define the research sample so that the data obtained would be relevant, minimally subjective, and representative of the domain under study. Finally, we had to decide how to collect the data to maximize the number of responses and address the ethical aspect of the research, which is absolutely critical in the field of cybersecurity.

The complexity of managing cybersecurity increases with the size and complexity of the system in which it is operated. For this reason, we decided to focus on the segment of the largest organizations in the Czech Republic, aiming to obtain data from respondents from both the public and commercial sectors. As a minimum threshold for the research sample, we set 250 employees, which corresponds to the category of a large enterprise according to the terminology of the European Commission's recommendations from 2003 (European Commission, 2003). According to the Czech Statistical Office, as of December 31, 2022 (Czech Statistical Office, 2023), there were 2,411 such organizations, approximately 300

of which are currently regulated by the Act on cybersecurity 181/2014 Coll. (National Cyber and Information Security Agency, 2014).

A total of 60 organizations from various fields were approached to obtain data from at least fifty respondents. We chose to collect data through questionnaire surveys combined with controlled expert interviews. The questionnaires regarding security were directed at the organizations' information security management staff, typically CISOs. Eventually, we managed to obtain data from 52 respondents, 32 of whom are regulated under the Act on cybersecurity. As of December 31, 2022, 414 entities were regulated in the Czech Republic under the Act on cybersecurity. (National Cyber and Information Security Agency, 2023). In total, 30 organizations fall into the public sector and 22 into the commercial segment. The second questionnaire focused on user satisfaction with the organization's security policy. This was addressed to regular IT users from various departments of the organizations in the research sample after consultation with the individual entities. The final phase of data collection was conducted through structured expert interviews with representatives of security and IT departments. A total of 65 respondents from large enterprises helped us uncover the context of organizations from a security management perspective, including specific information not covered by survey research. The structure and number of respondents, including the data collection methods used, are shown in Tab. 1.

Tab. 1: Respondent's position and methods used

Method	Respondent's position	Company size (No. of employees)	No. of respondents
Questionnaire 1	CISO	Large (>249)	52
Questionnaire 2	User	Large (>249)	285
Structured interview	IT/security manager	Large (>249)	28
Structured interview	IT director	Large (>249)	23
Structured interview	CISO	Large (>249)	14

Source: own

During the data collection, we placed the utmost emphasis on the ethical aspect of the research, as the provided data are confidential, and a leak could endanger the security of the organizations involved in the research. Therefore, anonymization and aggregation of all provided information is an absolute necessity. Due to the relatively small research sample, we decided to use a heuristic analysis supported by selected methods of probability theory and information theory instead of conventional statistical methods. The data collection took place in the second half of 2022 and the first half of 2023 in the Czech Republic. The obtained data were processed using Microsoft Excel tools and R statistical software.

An important question in the research was the decision on how to quantify the level of security in an organization. These data are not publicly available due to their sensitive nature, and each company approaches the issue differently. In organizations where an information security management system is implemented, a qualitative risk analysis is usually carried out. However, this analysis is not quantitatively comparable to the risk analysis of another entity, even though it follows a similar methodology. There is a lack of information on how an organization stands in terms of cybersecurity protection compared to similar entities in the market. For this reason, we decided to use the CIS controls guidelines for this purpose, which cover key elements of organizational security across eighteen domains. Given the research sample, oriented exclusively towards large organizations, we could utilize the full complexity of measures in the organizational mode. In creating the questionnaire, we formulated a question for each measure from the eighteen domains with the response options "applied" or "not applied," without the possibility of not responding. Of course,

the reader can argue that often, an organization has partially addressed measures, and this objection is relevant. However, when collecting data, we had to consider the time it took to complete more than 160 questions. Increasing the complexity of the questionnaire would then have a significant impact on its return rate. The data obtained were evaluated on a scale of 0–100% according to the number of measures applied for each domain, and the arithmetic mean was calculated across domains. Any organization can follow this approach and compare the results with reference values according to individual sectors. For the purposes of further work, let's label this variable as *T*. Then *T* takes on the values, we have chosen as follows: very low (the value is from the interval [38;56]), low ((56;67]), medium ((67;75]), high ((75;85]), and very high ((85;99]).

The second variable monitored in our research is the level of knowledge of decision-makers in the field of cybersecurity. For this purpose, we decided to utilize Bloom's taxonomy model and its cognitive domain. The first level of Bloom's taxonomy is the knowledge level, where learners are expected to recall information and facts. At this level, students are required to demonstrate their ability to remember previously learned information (Anderson et al., 2001). The second level of Bloom's taxonomy is the comprehension level, where learners are expected to show their understanding of the material by explaining, summarizing, or paraphrasing information (Krathwohl, 2002). The third level is the application level, where learners are expected to use previously learned information to solve problems or complete tasks (Anderson et al., 2001). At this level, learners apply their knowledge to new situations, often with guidance or assistance from the teacher. The fourth level is the analysis level, where learners are expected to break down complex information into its constituent parts and identify the relationships among them (Krathwohl, 2002). The fifth level is the synthesis level, where learners are expected to combine parts of knowledge to create a new whole or produce something original (Anderson et al., 2001). This level involves higher-order thinking skills, such as creativity and problem-solving. The highest level of Bloom's taxonomy is the evaluation level, where learners are expected to judge the value, quality, or effectiveness of something based on a set of criteria (Krathwohl, 2002). We mapped similarly the knowledge level of the given managers on a scale of 0–4. Zero corresponds to no or minimal knowledge, while four indicates a high maturity of the manager with capabilities for critical evaluation and defense of solutions. In this case, we did not use the option of directly addressing these managers and their self-assessments, as the outputs could be subjectively biased. Instead, we decided to expand the original questionnaire and obtain evaluations from the employees responsible for security in the organization. The questionnaire accounted for the possibility of multiple decision-makers in the process of approving investments in security, each with a different influence. Let us denote this variable as *S*. Then *S* takes on the values very low, low, medium, high, and very high.

Analogously, we approached the third monitored variable, which is the willingness of decision-makers to educate themselves in the field of cybersecurity. Similar to the previous case, we utilized Bloom's taxonomy and its affective domain. According to the developers of the revised Bloom's taxonomy (Taba, 1965), the affective domain includes how we deal with things emotionally, such as feelings, values, appreciation, enthusiasm, motivations, and attitudes. There are five levels in the affective domain, moving through the lowest-order processes to the highest: receiving, responding, valuing, organizing, and characterizing. We mapped similarly the levels of willingness to educate on the various stages of the affective domain using a 0–4 point scale. Zero signifies a level where cybersecurity is completely outside the decision-maker's focus. In contrast, a score of four denotes a state where cybersecurity becomes a passion for the manager, who actively studies available security resources, influencing their behavior and decision-making. With this approach, they also positively affect other employees. Let's denote this variable as *W*. Then *W* takes on the values very low, low, medium, high, and very high.

Cybersecurity investment by large organizations is a critical aspect of their operational strategy, given the increasing prevalence and sophistication of cyber threats. These investments are not only a defensive measure but also a crucial part of maintaining business integrity and customer trust. The magnitude and allocation of these resources vary widely among organizations but are generally

substantial, reflecting the high stakes involved. As part of the research, we decided to evaluate the share of spent resources of the organization on the total expenses of the given company. This share then takes on values on a scale of 0–15%. Let us denote the variable volume of resources invested by organizations in cyber security as *V*. Then *V* takes on the values, we have chosen as follows: very low (the value is from the interval [0;0,5]), low ((0,5;1]), medium ((1;3]), high ((3;5]), and very high ((5;15]).

The goal of security management in an organization is a high level of resistance to threats combined with a positive user experience. With the help of the NIST standard (Grassi et al., 2017), we defined a set of questions aimed at IT users of the same organizations that provided us with the data for the first part of the research. On a scale of 0–3, respondents answered how they are influenced by the organization's security rules during their work. Zero corresponds to a very negative state of the user, in which he is frustrated by the set conditions that prevent or inhibit him from performing work activities. On the contrary, the three corresponds to the fact that the user perceives security as an integral part of his work, which is not limited by security rules. Let us denote the user experience variable as *U*. Then *U* takes on the values very negative, negative, positive, and very positive.

The last variable entering the research is the contextual variable, related to the legal regulation in the field of cyber security. Information on whether the organization is subject to regulation under Act 181/2014 Coll. (National Cyber and Information Security Agency, 2014) is not public. Let us denote this variable as *L*. Then *L* takes on just the two values regulated, and not regulated. All variables defined above are shown in Tab. 2.

Tab. 2: Variables characterizing organizations

Denotation	Variable	Number of values
T	Total security score of the organization	5
S	Security knowledge status of decision-makers	5
W	The willingness of decision-makers to educate themselves	5
V	The volume of resources invested in cybersecurity	5
U	User experience	4
L	Legislation	2

Source: own

2.2 Probability theory tools

Mutual information and Information measure of dependency

Mutual information is a concept from information theory that measures the amount of information we obtain about one random variable by observing another. The definition of mutual information *MI*(*X*;*Y*) between two random variables *X* and *Y* is given by:

$$MI(X;Y) = \sum_{x \in X} \sum_{y \in Y} p(x,y) \cdot \log\left(\frac{p(x,y)}{p(x) \cdot p(y)}\right) \quad (1)$$

where: $p(x,y)$ – the joint probability distribution function of *X* and *Y*; $p(x)$ and $p(y)$ – the marginal probability distribution functions of *X* and *Y*, respectively.

Equation (1) can also be seen as a measure of the divergence (known as a Kullback-Leibler divergence) between the joint distribution $p(x,y)$ and the product of the individual distributions $p(x) \cdot p(y)$. If *X* and *Y* are independent, i.e., $p(x,y) = p(x) \cdot p(y)$, then the mutual information is zero, indicating that knowing *X* provides no information about *Y* (Manning et al., 2008).

To quantify the strength of influence between the above-mentioned variables, we computed mutual information for each pair of variables. To be precise: we do not know the actual probability distributions, we take the relative frequencies from the above-described

Tab. 3: Contingency table for variables *W* and *S*

	Variable *S*					n_{j}
Variable *W*	8	1	0	0	0	9
	2	5	3	3	0	13
	0	2	2	2	0	6
	0	2	5	2	2	11
	0	0	1	2	10	13
$n_{i.}$	10	10	11	9	12	n = 52

Source: own

contingency tables (Tab. 3) as their estimates. So, Equation (1) for computation of an estimate of mutual information *MI*(*W*,*S*) between two considered variables *W* and *S* changes to:

$$MI(W;S) = \frac{1}{n}\sum_{i,j} n_{i,j} \cdot \log_2\left(n\frac{n_{i,j}}{n_{i.} \cdot n_{.j}}\right) \quad (2)$$

where: $n_{i,j}$ – the number appearing on the i^{th} row and j^{th} column in the contingency table; $n_{i.}$ and $n_{.j}$ are the corresponding row and column sums, respectively; n – a total sum in the contingency table, i.e., for Tab. 3, n = 52.

Let's remember a few basic characteristics of mutual information. It gauges the strength of the relationship between variables; the more connected they are, the greater their mutual information. Mutual information is non-negative (it is zero for independent variables). It is also always less than the Shannon entropy of either of the variables involved. Consequently, we frequently opt for its normalized form, commonly referred to as the information measure of dependence defined by the formula:

$$IMD\ (W,S) = \frac{MI\ (W,S)}{\min\left(H(n_{i.}), H(n_{.j})\right)} \quad (3)$$

where:

$$H(n_{i.}) = -\frac{1}{n}\sum_i n_{i.} \cdot \log_2\left(\frac{n_i}{n}\right),$$
$$H(n_{.j}) = -\frac{1}{n}\sum_j n_{.j} \cdot \log_2\left(\frac{n_{.j}}{n}\right). \quad (4)$$

The values of mutual information along with the information measure of dependence pertaining to the variables under examination are systematically arranged in Tab. 4, adhering to a descending sequence based on IMD. The highlighted figures represent those identified by experts as significant and necessitate accurate representation within the ensuing model.

Compositional probabilistic models

A six-dimensional probability distribution encompassing the variables in question is characterized by $2 \cdot 4 \cdot 5^4 - 1 = 4{,}999$ parameters (probabilities). The task of ascertaining this extensive number of parameters exceeds

Tab. 4: Values of information measures for pairs of variables

	WS	*ST*	*TU*	*WT*	*VU*	*VT*	*SU*	*WL*	*WU*	*WV*	*SV*	*SL*	*TL*	*UL*	*VL*
MI	0.924	0.737	0.450	0.485	0.416	0.377	0.301	0.132	0.266	0.265	0.241	0.096	0.090	0.043	0.040
IMD	0.407	0.319	0.227	0.213	0.209	0.169	0.152	0.135	0.134	0.119	0.108	0.098	0.092	0.044	0.041

Note: *W* – the willingness of decision-makers to educate themselves; *S* – security knowledge status of decision-makers; *T* – total security score of the organization; *U* – user experience; *V* – the volume of resources invested in cybersecurity; *L* – legislation.

Source: own

the expertise capacity of any expert. Consequently, this necessitates the consideration of a subset of distributions that are delineated by a reduced quantity of parameters.

A compositional model is conceptualized as a probability distribution formulated through the aggregation of its marginal distributions of lower dimensions, utilizing a composition operator (Jiroušek, 2011). The present analysis is restricted to graphical compositional models, wherein the marginal distributions are depicted through the cliques within a graph. By interpreting the pairs of variables highlighted in Tab. 4 as the edges of a graph in Fig. 1, the compositional models are construed as six-dimensional probability distributions characterized by the following properties:

$$\pi(L,S,T,U,V,W) = \pi(S,T,W) \rhd \\ \rhd \pi(T,U,V) \rhd \pi(L,S,W) = \pi(S,T,W) \cdot \\ \cdot \pi(U,V|T) \cdot \pi(L|S,W) \quad (5)$$

In our discourse, we employ only a few specific symbols. For a deeper understanding of compositional models see Jiroušek (2011). Consider a probability distribution π, defined for variables *r*. Let *s* be a proper subset of *r*, $\pi^{\downarrow s}$ denotes the marginal distribution of π, constricted to the variables *s*. Notice that the marginal distribution for an empty set, $\pi^{\downarrow \emptyset}$, equates to 1.

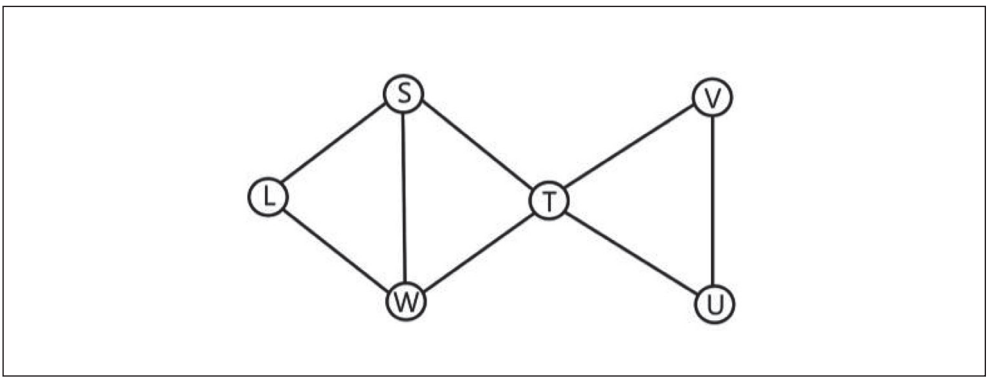

Fig. 1: Decomposable graph with three cliques: {*L,S,W*}, {*S,T,W*}, and {*T,U,V*}

Source: own

Consider distributions π and κ defined for variables *r* and *t*, respectively. The composition of these distributions into a more-dimensional distribution, denoted as $(\pi \rhd \kappa)$, yields a distribution defined for variables $r \cup t$. It is determined by:

$$(\pi \rhd \kappa) = \frac{\pi \cdot \kappa}{\kappa^{\downarrow r \cap t}} \quad (6)$$

If the right-hand-side formula in Equation (6) is defined. It is pertinent to note that the composition of two marginal distributions of a multi-dimensional probability distribution is always defined. As highlighted in Jiroušek (2011), the composition operator is non-commutative and non-associative. Consequently, to disambiguate expressions akin to those found in Equation (5), it is imperative to adhere to a left-to-right application of operators, barring explicit directives to alter this sequence through the use of parentheses.

Recall from graph theory that a simple graph with cliques $c_1, c_2, \ldots, c_k$ is said to be decomposable (or triangulated) if the cliques can be enumerated so that they meet the so-called running intersection property (RIP): $\forall i = 3,4, \ldots, k \; \exists \, j \; (1 \leq j < i)$: $c_i \cap (c_1 \cup \ldots \cup c_{i-1}) \subseteq c_j$.

Probability distribution π for variables *r* is said to be decomposable if there exists a decomposable graph $G = (r, E)$ with cliques $c_1, c_2, \ldots, c_k$ such that $\pi = \pi^{\downarrow c1} \rhd \pi^{\downarrow c2} \rhd \ldots \rhd \pi^{\downarrow ck}$, if the ordering $c_1, c_2, \ldots, c_k$ meets RIP.

Note that it was shown that for decomposable distribution π, $\pi = \pi^{\downarrow c1} \rhd \pi^{\downarrow c2} \rhd \ldots \rhd \pi^{\downarrow ck}$ for all RIP orderings of the cliques

c_1, c_2, …, c_k (Jiroušek, 2011). When designing the required model, we will also employ the following statement.

Proposition. Let π be a decomposable distribution with the decomposable graph *G*, the cliques of which are c_1, c_2, …, c_k. Consider any probability distribution κ of variables $\bigcup_{j=1}^{k} cj \cdot$ If $\pi^{\downarrow j} = \kappa^{\downarrow j}$ for all j = 1, ..., k, then $H(\kappa) \leq H(\pi)$.

Pairwise dependence corrections

As previously mentioned, experts have identified eight pairs of variables whose mutual dependencies are deemed crucial for reflection within the resultant model. Should the marginal probabilities of the model be directly inferred from the relative frequencies delineated in the contingency table (Tab. 3), it might lead to what is colloquially referred to within the machine learning domain as "overlearning." Such a predicament would render the model inept at accommodating scenarios that deviate from the explicitly observed data, for instance, certain combinations of values not previously encountered or recorded by the contributing experts (e.g., recall the variables *W* and *S* listed in Tab. 3, where the frequency of managers' very high willingness to learn combined with their medium level of cybersecurity knowledge is equal to 0, however, the existence of such a combination is possible). Nevertheless, these experts acknowledge the potential for such variable configurations to manifest in distinct organizational contexts. This recognition underscores the necessity to imbue the model with a certain degree of epistemic humility, thereby enabling it to accommodate a broader spectrum of possibilities without stringent reliance on the observed data alone. This approach necessitates the incorporation of a calculated measure of ignorance into the model to ensure its robustness and applicability across varying circumstances.

Tab. 5: Modification for contingency table for variables *W* and *S*

	Variable *S*					∑
Variable *W*	8 + ε	1 + ε	ε	ε	0	9 + 4ε
	2 + ε	5 + ε	3 + ε	3 + ε	ε	13 + 5ε
	ε	2 + ε	2 + ε	2 + ε	ε	6 + 5ε
	ε	2 + ε	5 + ε	2 + ε	2 + ε	11 + 5ε
	0	ε	1 + ε	2 + ε	10 + ε	13 + 4ε
∑	10 + 4ε	10 + 5ε	11 + 5ε	9 + 5ε	12 + 4ε	n = 52 + 23ε

Source: own

In the probability theory, the articulation of ignorance is conventionally achieved through a uniform distribution. Hence, to address the issue previously delineated, a minor alteration was applied to all eight contingency tables. To elucidate this methodology, we refer specifically to Tab. 3. Initially, a consultation with domain experts was conducted to ascertain the presence of zeroes within the contingency table that ought to be preserved within the model, thereby assessing the existence of any inherent logical relationships.

In examining the contingency table that maps the interrelation between variables *W* and *S*, the consensus among experts was that only zeroes positioned in the upper-right and lower-left boxes should be retained. Consequently, the task became to identify an appropriate positive value of ε, such that the modified contingency table (Tab. 5) would align with the expert panel's stipulations. To underpin the determination of an apt ε value, the calculation of mutual information and the measure of information dependence for various ε values was undertaken (detailed in Tab. 6). After a thorough review, the experts unanimously agreed on selecting ε = 0.15. Their rationale was twofold: a value exceeding 0.15 would lead to an excessive dilution of informative content, whereas lower ε values might disproportionately emphasize the data derived from organizations already included in the study.

Tab. 6: Decrease of IMD with increasing ε in Tab. 5

	ε										
	0.00	**0.05**	**0.10**	**0.15**	**0.20**	**0.25**	**0.30**	**0.35**	**0.40**	**0.45**	**0.50**
IMD	0.407	0.38	0.361	0.344	0.33	0.317	0.305	0.294	0.283	0.274	0.265
Δ (%)	0.000	6.400	11.200	15.300	19.900	22.100	25.100	27.800	303.000	32.600	34.700

Source: own

Iterative proportional fitting

The method under discussion was designed in 1940 (Deming & Stephan, 1940), albeit its convergence was substantiated at a later stage by (Csiszar, 1975). With the availability of the composition operator, the description of this procedure becomes straightforward.

Consider π_1, π_2, ..., π_k, as a series of probability distributions, each defined over a distinct group of variables c_1, c_2, …, c_k (the ordering is arbitrary). The initial phase of the procedure involves establishing a uniform probability distribution, denoted as κ_0, across the variables encompassed within the union of all c_j groups. The method consists of iterative calculating:

$$\kappa_i = \pi_{(i \bmod(k))} \rhd \kappa_{i-1} \tag{7}$$

To rephrase, we sequentially process distributions c_1, c_2, …, c_k, composing each with the outcome from its preceding step. Upon reaching the final distribution in the sequence c_k, the procedure recommences with c_1, persisting in this cyclical manner until achieving convergence to the stipulated level of precision. This approach is underpinned by findings from (Csiszar, 1975), which ascertain that the Shannon entropy of the eventual distribution, $H(\lim_{i\to\infty} \kappa i)$, is either equivalent to or surpasses the entropy of any given distribution π (defined for variables $\bigcup_{j=1}^{k} c_j$) that includes π_1, π_2, ..., π_k as its marginal distributions. In light of this, coupled with Proposition, it is deduced that a six-dimensional decomposable framework (Fig. 1), whose three-dimensional components are derived from two-dimensional distributions via the iterative proportional fitting process, constitutes the optimal entropy augmentation of all the chosen two-dimensional distributions.

3. Results and discussion

The previous section elucidated the development of a six-dimensional decomposable compositional model in a form given in Equation (5). This construction was supported by the analysis of mutual information, which guided the selection of a decomposable graph structure. To mitigate the potential for overlearning the corresponding two-dimensional contingency tables were slightly modified. The whole process culminated in the identification of maximal entropy distributions $\pi(S,T,W)$, $\pi(T,U,V)$, and $\pi(L,S,W)$, which collectively comprise the model $\pi(L,S,T,U,V,W)$. With the model thus defined in Equation (5), we are positioned to apply the computational techniques outlined in Bína et al. (2021) for the calculation of any marginal or conditional probabilities needed for inference processes.

3.1 Example 1

Let's look at how security regulation affects organizational behavior in terms of managers' willingness to learn, combined with the organization's overall level of security. The outputs from the model are shown in Figs. 2–3, where we have united the detailed probabilities into four quadrants for better clarity.

At first glance (highlighted in bold), the difference is visible in the upper left quadrant, i.e., for not regulated entities there is a significantly higher probability that managers with a low to medium willingness to educate themselves in the field of cyber security will make decisions in organizations with a low to medium level of security.

3.2 Example 2

We will proceed analogously in the following case. How does regulation in the field of cyber security affect the behavior of organizations with regard to the level of security combined with the amount of investment in their protection? Calculations from the model are shown in Figs. 4–5.

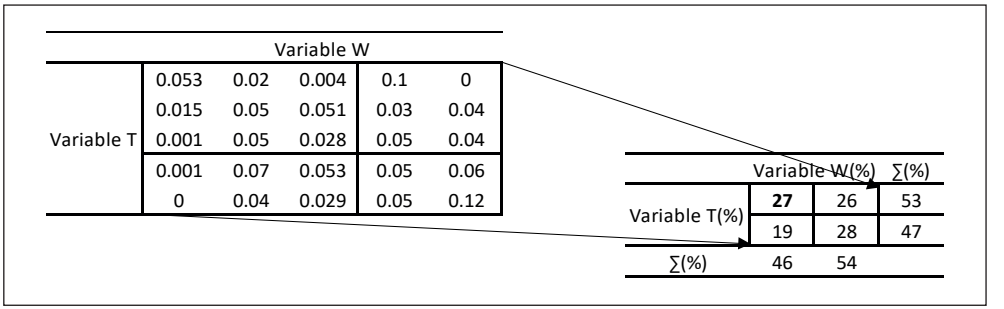

Fig. 2: **Conditional probability *T*&*W* under condition *L* (regulated)**

Source: own

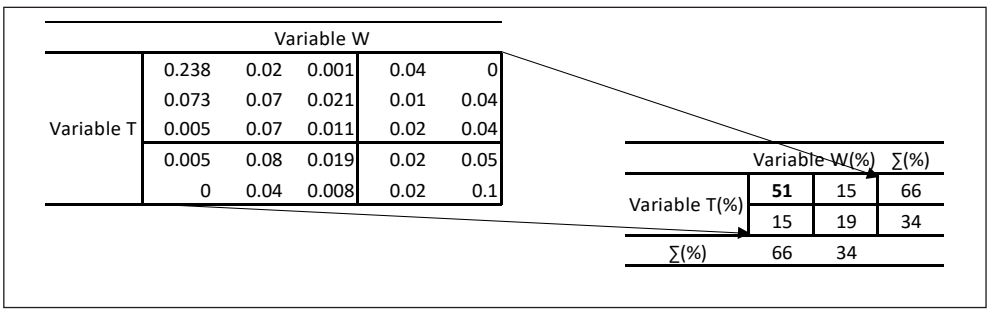

Fig. 3: **Conditional probability *T*&*W* under condition *L* (not regulated)**

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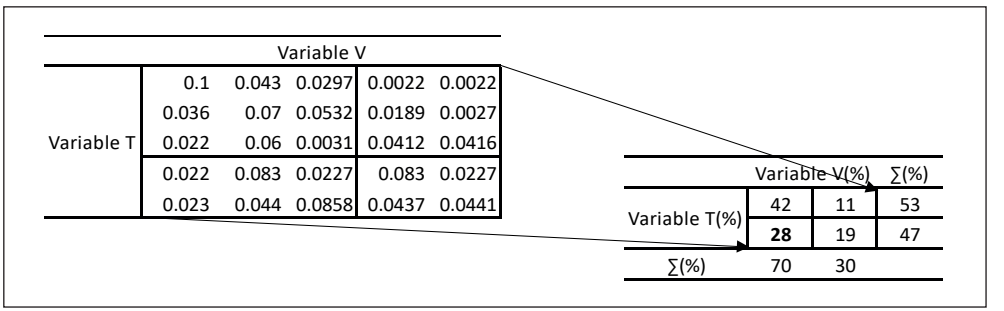

Fig. 4: **Conditional probability *T*&*V* under condition *L* (regulated)**

Source: own

In this case, regulation has a decidedly lower influence on the behavior of organizations than in the previous example. As can be seen from the values in the lower left quadrant of the tables (highlighted in bold), among regulated entities, organizations with higher levels of security are 8% more likely to invest lower to moderate amounts of resources in their protection.

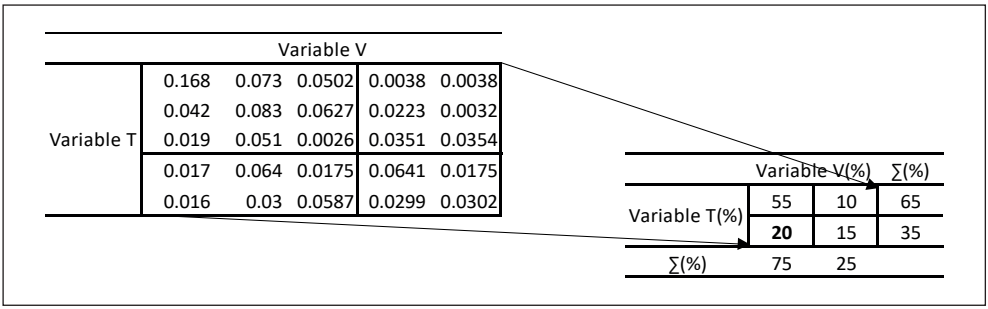

Fig. 5: **Conditional probability *T*&*V* under condition *L* (not regulated)**

Source: own

3.3 Example 3

In this case, we will address a situation where we compare the behavior of organizations with and without regulation based on the probability of occurrence of a combination of the organization's security level and user experience. Security practice is more inclined to the rule of decreasing user satisfaction with increasing

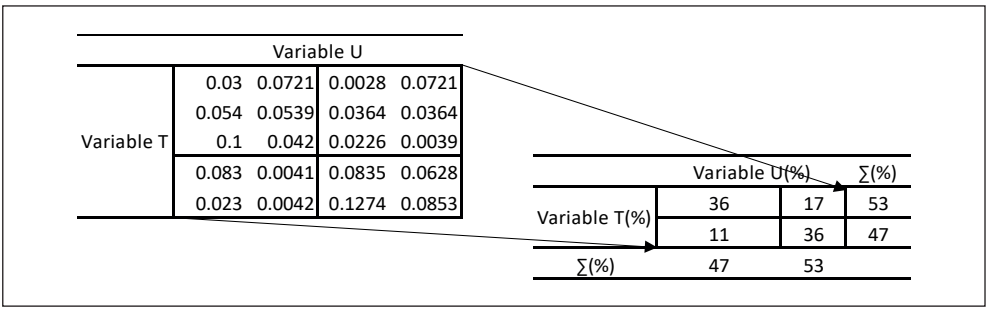

Fig. 6: **Conditional probability *T*&*U* under condition *L* (regulated)**

Source: own

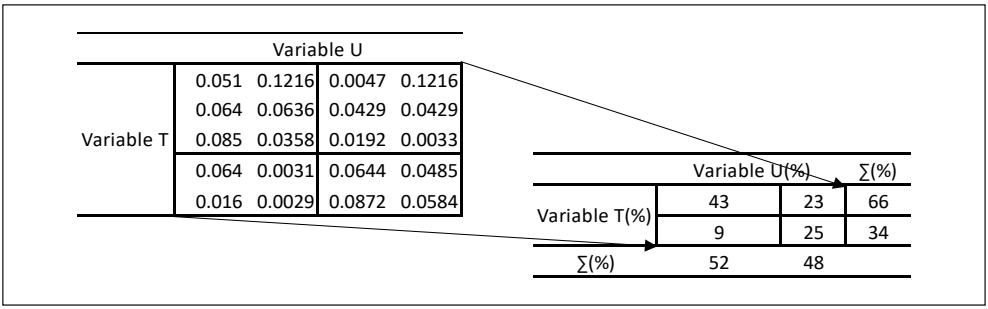

Fig. 7: **Conditional probability *T*&*U* under condition *L* (not regulated)**

Source: own

firm resistance to cyberspace threats. Let's look at Figs. 6–7 to see how the data processed in the model can be interpreted.

The model shows the biggest difference between regulated and unregulated subjects this time in the lower right quadrant, where there is a combination of high level of security and high user satisfaction. These outputs indicate that regulated entities are using new technologies supporting the automation and orchestration of some actions and are thus not burdensome for users.

Analogously, it is possible to use the model for any combination of variables *L*, *S*, *T*, *U*, *V*, *W*.

3.4 Reference model

The partial goal of this article was to perform an analysis of the state of cyber security in large enterprises. Based on the methodology described in previous part of the article, we compiled a graph (Fig. 8) of reference values for individual sectors. Each of the selected sectors is represented by at least four respondents working in the given area. For example, large educational institutions, typically universities, were included in the education category, the ICT category consists of organizations providing IT and cloud services and telecommunications operators, the services area is represented by sellers of goods, typically retail chains. In general, regulated industries fare better in terms of security than organizations that are not affected by legislation. Financial sector entities (e.g., banks) are the most protected, followed by healthcare organizations (e.g., large hospitals) and critical information infrastructure (CII) enterprises. The lowest security score achieved is associated with the media and educational institutions sector.

3.5 Discussion

Using the methods described, based on the 52 top security managers' knowledge and the data they used to characterize their organizations (52 large enterprises), we created a probabilistic model including a total of six variables related to cyber security. On the basis of this model, we are able to derive the marginal and conditional probabilities of all combinations of observed variables. Outputs from the model can serve the authorities regulating

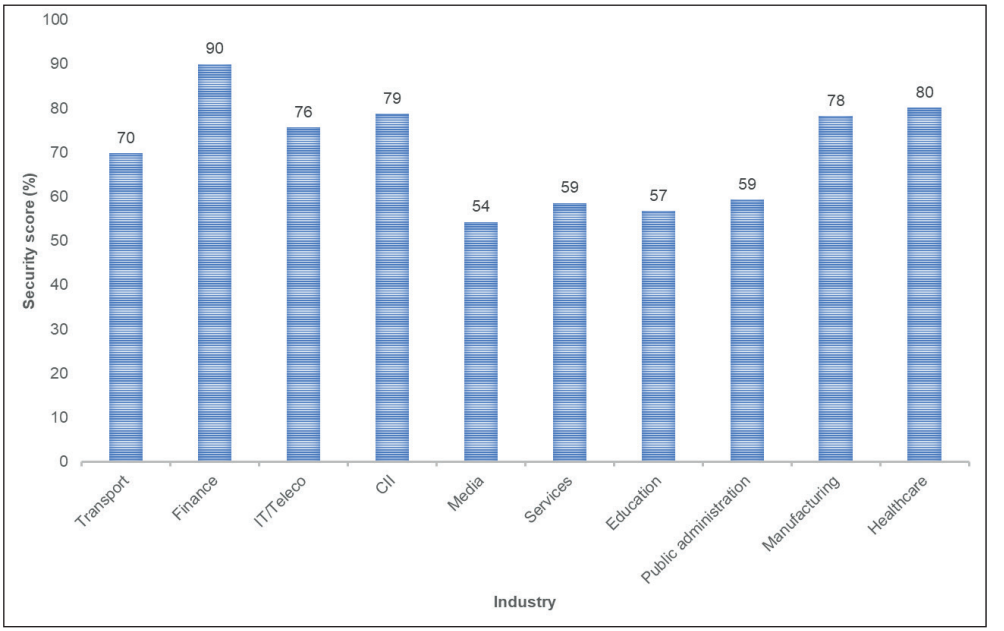

Fig. 8: Reference model for the overall security posture score

Source: own

cyber security conditions within the European Union. Union law in this area is governed by the form of harmonization, i.e., it carries the same elements of the transposed directives (European Parliament and the Council, 2016a). The knowledge contained in the model can also serve organizations that specialize in products and services in cyber security, including training centers. Conversely, the reference model of the state of cyber security by industry may interest managers responsible for security management in large organizations, who can compare their organization's security score with benchmarks using the CIS controls framework.

National Cyber and Information Security Agency is a reliable source of information in the field of cyber security for regulated as well as unregulated organizations in the Czech Republic. The situation is similar in other EU countries, including the umbrella organization European Union Agency for Cybersecurity (National Cyber and Information Security Agency, 2023). Every year, National Cyber and Information Security Agency publishes a report on the state of security in the Czech Republic (National Cyber and Information Security Agency, 2024) compiled based on a questionnaire survey of regulated entities according to the Act on cybersecurity 181/2014 Coll. (National Cyber and Information Security Agency, 2014). Our study expands the spectrum of information on domains that this report does not provide.

The results of our research confirm the conclusions of the authors (Kajava et al., 2007) that the education of top management in the area of cyber security is an important factor influencing the overall level of security of a given organization. However, our findings broaden the view of managers' willingness to educate themselves in cyber security. Example 1 demonstrates the fact that unregulated entities with a low to medium level of security are almost twice as likely to have top managers with a low to medium willingness to educate themselves in cyber security compared to entities that are regulated. This effect confirms that the current regulation motivates decision-makers to educate themselves in cyber security. Furthermore, research has shown that cyber security regulation, in general, helps enforce security rules in organizations. The research outputs are fully in line with the wording of the EU directive (European Parliament and the Council, 2022), which explicitly requires the education of top management in the field of cyber security. However, this directive will not be reflected in the Czech legislation until the second half of 2024.

Example 2 provides an economic perspective on information security management. Unregulated entities with high levels of security are less likely to invest low to moderate resources in security compared to regulated organizations. This result suggests that achieving a high level of security is possible with lower costs, however, regulation in the industry increases these costs. Example 3 discusses a comparison between the behavior of regulated and unregulated organizations in relation to cybersecurity and user experience. It highlights the trade-off where increased security often reduces user satisfaction. The analysis of data (from Figs. 6–7) shows the most significant difference in the lower right quadrant, where both high security levels and high user satisfaction coexist. This suggests that regulated organizations are adopting advanced technologies that automate and streamline certain security actions, minimizing the impact on users and improving overall satisfaction.

According to Leszczyna (2021), there is a whole range of methods and frameworks to measure the level of cybersecurity in an organization. Each method has its limits. For our work, we decided, like Lykou et al. (2018), to use the self-assessment method, which provides a reasonable degree of objectivity and is not expensive, unlike commercial analyses. The assessment methodology, including the framework used, can serve the responsible security manager as a simple tool to detect security vulnerabilities. The reference values shown in Fig. 8 can then be used for comparison with the result of the organization's security level in the listed fields.

Our research is primarily based on data obtained from CISOs of 52 large companies operating in the Czech Republic. The relatively low number of respondents, despite all our modifications, to some extent limits the quality of the resulting model. Another factor that can affect the work output is the respondent's different subjective perception of the situation. Although we tried to be accurate, some degree of subjective bias on the part of the respondents is likely. In the contribution, among other things, we also address the resources spent on cyber security. However, it was unrealistic to obtain a specific figure on the financial costs. Therefore, we proposed this variable as the share of costs spent on cyber security in the total costs of the organization. The value of the organization's total costs, which

is different for organizations operating in different fields, can be misleading. However, the proposed probabilistic model provides a full set of combinations of observed variables. Examples 1–3 are just a taster for other combinations of selected parameters. In the future, it will certainly be interesting to enrich the research with the values found after the introduction of the new act on cyber security into the national legislation and to analyze the obtained data from the point of view of causality.

Conclusions

The central aim of this study was to scrutinize the strategic behaviors exhibited by major corporations within the realm of information security management. By collating and analyzing pertinent data, the research endeavored to construct a theoretical framework that elucidated the dynamics and interconnections among the variables under investigation. This endeavor sought not only to chart the landscape of information security practices among large enterprises at that time but also to contribute to the existing body of knowledge by offering a comprehensive model that encapsulated the intricate relationships between these key factors. Subsidiary objectives encompassed a thorough examination of the state of cybersecurity within both commercial entities and public sector organizations, segmented by specific industry sectors. This analytical endeavor aimed to delineate the cybersecurity landscape retrospectively, identifying prevalent vulnerabilities, defense mechanisms, and compliance levels within distinct sectors. Through this sector-specific analysis, the study intended to unveil patterns, challenges, and best practices in cybersecurity management, thereby facilitating targeted improvements and strategic planning for enhanced security measures across the board.

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