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Examination of The Relationship Between Sustainable Industry 4.0 and Business Performance

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Abstract

A circular economy recycles previously manufactured products at the end of their lifecycle with minimal or zero waste generation and the use of additional new resources. The priorities of the recycling system include waste minimisation, reuse, remanufacturing and improvement. Innovative methods can therefore be integrated into factories to ensure waste is used to feed energy systems, rather than them exacerbating deforestation. As part of the research presented in this paper, we examined the impact of sustainability factors within Hungarian food companies, Industry 4.0 tools, as well as other factors that support or hinder business performance. The article aims to present the tools used for evaluating the efficacy and competitiveness of the business models of Hungarian food companies within the context of Industry 4.0.

The questionnaire survey was conducted between 2019 and 2020, during which data were collected from 276 food companies. The data were subsequently analysed using a broad range of statistical methods, including Cronbach's alpha index, factor analysis, K-mean clustering, one-way analysis of variance, cross-tabulation analysis, significance-effect matrix, Fornell-Larcker criterion, composition reliability index, and for the PLS path analysis, mean explained variance index, heterotrait-monotrait ratio, and predictive relevance. Researching sustainability factors is a means by which to strike a balance between economic, social and ecological factors so that a company can be efficient, effective and functional at the same time. Sustainable Industry 4.0 is an area of research that has yet to be explored by food companies.

Keywords: circular economy, sustainability factors, competitiveness, Industry 4.0 tools, risk factors
JEL Classification: F12, C38, L16

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1. INTRODUCTION

In this period of rapid globalisation and industrialisation, companies are becoming more aware of sustainability challenges, necessitating a greater need to incorporate ethical and sustainable business practices to address social, economic and environmental issues (Gupta et al., 2021; Pimonenko et al., 2021). Within this context, Industry 4.0 seeks to help companies attain an advanced level of operational efficacy and productivity, as well as higher value solutions that impact on the sustainability of a business through highly connected Internet technologies and progressive algorithms. Most importantly, Industry 4.0 is about technical procedures that generate value added and encourage effective knowledge management practices. The tremendous potential for innovation and growth in competitiveness means Industry 4.0 may also help to improve the sustainability of the current industrial system, too.

In recent years, the increasing need for and rapidity of the digitalization of industrial processes means that Industry 4.0 has become an important tool with which companies can improve their performance. It is especially important with regard to providing solutions to those issues posed by the current digitalization revolution. Like other continents, Europe, including Hungary, needs Industry 4.0 to establish an appropriate system for driving and improving competitiveness. In the case of Hungary, international corporations already have the appropriate expertise and capital to utilise the opportunities provided to them by industrial development. Yet, how Industry 4.0 will change and influence competitiveness between non-sustainable and sustainable industries within countries requires more research.

The research presented in this article focuses on promoting the most efficient and sustainable use of natural resources, as well as the importance of the principles of the circular economy, which both have a positive impact on the environment. To decrease pollution, the ecological part of the sustainability factor demands businesses wrap products in reusable packaging. Sustainable Industry 4.0, on the other hand, is an area of research that has yet to be explored by food companies. The research topic aims to highlight the importance of novel technologies in the food industry in Hungary, where they can be assessed for production use, their impact on the economy, society and the environment, the efficacy of business models, and the level of competitivity of the industry.

The paper is structured as follows: Section 2 sets out the theoretical background and provides a summary of the economic, social and ecological dimensions of Sustainable Industry 4.0, including the impact of Sustainable Industry 4.0 tools. Section 3 presents the research objective, methodology and data, and includes detailed information on the geographical locations of food companies. Section 4 encompasses a discussion of the study's findings. Section 5 offers conclusions drawn from the results of the study; it also highlights the international dimension of the study and several important policy implications.

2. THEORETICAL BACKGROUND

2.1 Factors affecting the environmental, social and economic sustainability of Industry 4.0

Sustainable development is a developmental process that meets the needs of the present without compromising the needs of future generations. Sustainable Industry 4.0 addresses the impact of technologies on economic, social, ecological factors, innovation, competitiveness and growth, all of which are key measures of business success, as articulated in science and in practice. No single stakeholder can address only one dimension, as all three dimensions of sustainability are crucial for helping to identify consumer purchasing perceptions, as well as trade-offs that bring benefits in both the short and long term (Mazahir & Ardestani-Jaafari, 2020). To find common ground between these three dimensions, change is a necessary step.

In humanity's efforts to minimise its impact on the environment and improve living standards, it is facing one of the most difficult problems it has ever had. Those problems mostly involve giving priority to the abolition of famine, the provision of safe drinking water, the creation of respectable jobs and economic growth, the encouragement of responsible use and production, and the supply of low-cost, long-term energy (Chen et al., 2020). Although companies may achieve far-reaching changes in these areas, sustainability is only possible if everyone concerned participates in the process (Tang et al., 2016). In their studies, Gielen, et al. (2019) and Bonilla, et al. (2018) highlight the responsibility of all parties to protect the environment. This should not be left to companies alone, as their goal is not only to maximise profits, but also to keep consumers and societal needs in mind while simultaneously providing jobs and trying to protect the environment (Bonilla et al., 2018; Brous et al., 2020; Halaskova et al., 2021). Using waste technologies therefore plays an important role in reducing harmful greenhouse gases, contaminated soil and water. Innovative methods can therefore be integrated into factories to ensure waste is used to feed energy systems, rather than companies exacerbating deforestation and extending the life of coal-fired power stations (Chen et al., 2020).

Industry 4.0 is changing not only the tasks, but also the 'environment.' Several administrative activities (e.g., invoicing) and simpler operational activities (e.g., raw material preparation) are already automatically completed in the 'digital world.' Luthra and Mangla (2018) identified 18 challenges that Industry 4.0 may face in improving supply chain sustainability (Nagy et al., 2018). In conclusion, after reviewing all the studies, it can be said that the threats and opportunities associated with the implementation of Industry 4.0 remain uncertain, and that the related technologies have not been fully explored yet by researchers in terms of environmental sustainability. Moreover, with Industry 4.0, existing business models will develop, and the level of competitivity will improve on the basis of the actions listed below (Grabowska & Saniuk, 2022; Yu, et al., 2021; Gadekar et al., 2022).

1. Clarification of strategic objectives and the integration thereof into management systems.
2. Improvements in vision and strategy - planning, defining goals, launching strategic initiatives.
3. Enhancement of the monitoring, strategic execution and learning processes within a company.

3. RESEARCH OBJECTIVE, METHODOLOGY AND DATA

3.1 Research work and delimitation of the research area

Secondary material on the topic was gathered from international literary sources. In order to achieve the goal of the study, Industry 4.0 technologies, food production in Hungary, evaluation of company strategy, and their use within the corporate context were used as research foci in certain sub-areas.

Primary data collection was carried out on the basis of a questionnaire survey conducted between 2019 and 2020 during online professional events and in person or over the telephone. Figure 1 shows the structure of the questionnaire in terms of the particular subjects information being sought and the links between them; it is also the initial model for the PLS path analysis.

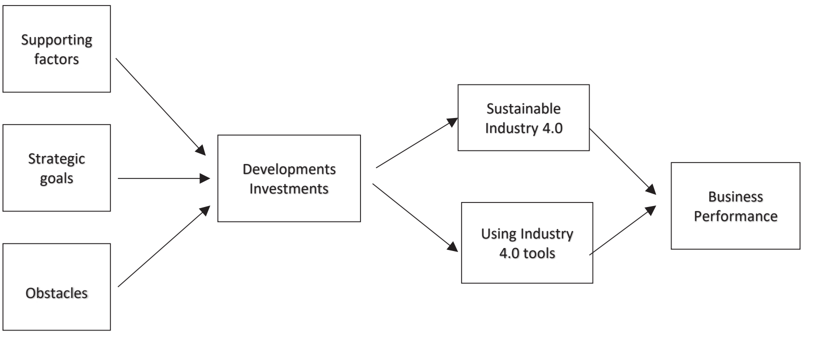


Fig 1. The theoretical framework of the questionnaire and first model for PLS path analysis. Source: own research

The aim of the model was to establish the strategic objectives of companies so as to determine those factors that hinder and/or support development. This would help to determine which Industry 4.0 tools should be given priority in order to support the sustainability of the economy, society and the environment, workplace performance, and the efficiency of companies during their development process. In Hungary, there are 1,157 food companies, of which 276 completed the questionnaire survey. Due to data cleaning, the number of appropriately completed surveys was reduced to 259. The questionnaire contained questions on seven main topics (see Table 1), the consistency of which was established on the basis of a reliability test. Of the 74 statements made, four had to be disqualified because Cronbach's alpha value was too low, thereby lowering the entire topic's alpha value.

Tab. 1 - Statistical reliability of food companies. Source: own research

Areas of interest	Subareas examined	No. of statements	No. of disqualified statements	Cronbach's alpha value
Planned strategic aims		10	0	0.804
Associate factors		8	1	0.773
Obstacles		12	1	0.876
Growth / Savings		7	0	0.985
Industry 4.0 tools		10	0	0.841
Sustainable Industry 4.0	Economic	8	0	0.786
	Social	9	1	0.804
	Ecological	9	1	0.928

Business performance	Efficacy	4	0	0.789
	Development	4	0	0.820
Total		74	4	

Cronbach's alpha values for all the other statements were sufficient. This result indicates the reliability and stability of the scales. As is evident in the table, all alpha values are above 0.7. For further research, the value of the Cronbach's alpha for the examined variables was checked for internal consistency.

3.2 Methodology

Data collection started with a pilot survey that yielded 45 responses from participants. Lessons were learned from the acquired data and e-mail feedback, and adjustments were made accordingly. In order to estimate the questionnaire's internal consistency, reliability tests were conducted. Cronbach's alpha coefficient is described as a measure for helping to test the reliability of data. The ideal value lies between 0.70 and 0.85.

Cross-tabulation was applied to the results of the research to demonstrate the link between two or more variables (Bamwesigye et al., 2020). Pearson's Chi-square (2) test was used in this study to test hypotheses concerning the nominal variables. In addition, cluster analysis enabled the dependent variables to be divided into the particular characteristics according to homogenous groups (Schöggl et al., 2020). Analyses of variance (ANOVA) were employed to indicate the outcome of independent factors or dependent variables (Beekaroo et al., 2019). The route model between the developed factors was created using the PLS path analysis method. Multiple measures related to the dimension's reliability and validity were also employed to complete the clarification of the reflecting external model in the PLS-SEM path analysis (see Table 2).

Tab. 2 - Indicators of reflective model fitting of external model. Source: own research

Subject of investiga-tion	Method applied	Calculation	Criterion	Source
Indicator reliability	Cronbach's alpha		Alpha > 0.7	Cronbach (1951)
Structural reliability	Composition reli-ability indicator (CR)	$\frac{(\sum_i \lambda_i)^2}{(\sum_i \lambda_i)^2 + \sum_i Var(\varepsilon_i)}$	CR > 0.7	Werts et al. (1974)
Conver-gence validity	Average Variance Extracted (AVE)	$\frac{\sum_i \lambda_i^2}{\sum_i \lambda_i^2 + \sum_i Var(\varepsilon_i)}$	AVE > 0.5	Fornell and Larcker (1981)
Discrimi-nation validity	Fornell-Larcker criterion	Each latent variable's square root of AVE values should be greater than the correlation coefficient between that latent variable and all other latent variables.		Fornell and Larcker (1981)

Discrimination validity	Heterotrait-monotrait ratio (HTMT)	(Average of pairwise correlation coefficients between manifest variables to two latent variables)/(Average of pairwise correlation coefficients between manifest variables to the same latent variables)→HTMT < 0.9	Henseler et al. (2015)

The model's compositional reliability index (Composite Reliability – CR > 0.7) and the standardised factor weights (> 0.5) should also be evaluated for convergence validity (Hair et al., 2021). The Average Variance Extracted (AVE> 0.5) approach was also employed. According to the Fornell & Larcker (1981) test, the AVE value for the latent variable should be bigger than the correlation rate between the other latent variables. This rule is also known as the Fornell-Larcker principle. According to Henseler, et al. (2015), if the HTMT indices are less than 0.9, discriminant validity is assumed. Given the importance of the study, multicollinearity was another factor that was tested, in this case, on the basis of the Variance Inflation Factor (VIF) index. Following the analysis of the external model, the following question arises: Are the model's direct links significant? A five-step structural model was created to evaluate the impact magnitude (f2), the goodness of fit (GoF), predictive relevance (Q2), and path model coefficients (β) (see Table 4) to check which latent variable module values could be applied to the given construct (Ujlaky et al., 2021).

Tab. 3 - Internal structural model fit criteria. Source: own research

Subject of investigation	Method applied	Criterion	Source
Impact magnitude	f2	Small: 0.02 < f2 < 0.15 Medium: 0.15 < f2 < 0.35 Large: 0.35 < f2	Henseler et al. (2009)
Goodness of fit	GoF = AVE/R^2	Small sample: 0.10 Medium sample: 0.25 Large sample: 0.36	Fornell and Larcker (1981)
Predictive relevance	Q2	Q2 > 0	Shmueli, et al. (2019)
Path model coefficients	β	p value < 0.05	Hair, et al. (2021)

To generate the regression model, path model coefficients were used. The reason for this is that an overlapping regression was split into two parts: independent and dependent variables. The first step was to calculate the direct effect of the independent variable on the outcome variable. Subsequently, the intermediate variables were calculated to measure the effect of the independent variable on the dependent variable (Gavurova et al., 2017b; D'Souza et al., 2020; Popova, 2021; Pereira-Moliner et al., 2021). The goal of the Importance-Performance Matrix Analysis (IPMA) is to classify historical factors that are moderately important for target ideas, but which perform poorly (i.e., low average factor values). IPMA was linked to the aggregate impact of each variable in the model. On the basis of a thorough examination of empirical literature and theory, the following hypotheses were formulated:

H1: There is a strong relationship between the location of food companies and sustainability clusters.

H2: High technological expenses, a lack of internal resources, and a shortage of competent labour are limiting the scope of Industry 4.0 innovations.

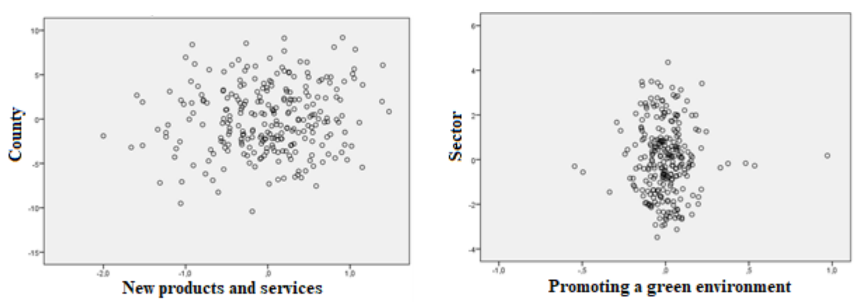
H3: The introduction of new IT technologies and their use has a considerable, beneficial and positive impact on the financial performance of food companies.

H4: Of all the sustainability factors, environmental factors have the greatest impact on corporate performance.

4. RESULTS AND DISCUSSION

4.1 Results of factor analysis of food companies

Factor analysis was applied to the data to validate the indications in the questionnaire. The validity of the major components thereof was explored using the most recent version of IBM SPSS Statistics 23 software. Those indicators that produced a low value in the model were subsequently extracted. The study included over 119 variables. After factor generation and outlier elimination, 112 variables were left in the sample, which were then grouped into 19 factors. Understanding how the variables are distributed is critical to the study's efficacy. Each variable was assumed to have a normal distribution, which is visually depicted in Figures 2a and 2b.



a) Interaction between counties and new products and services

b) Promoting a green environment and cross-sector collaboration

Fig. 2 - Relationships and distributions between variables. Source: own research

4.2 Food company clustering based on sustainability characteristics

The data was clustered using the K-means algorithm, which is a non-hierarchical grouping method. The results show that three kinds of food companies can be classified based on business performance, economic, social and ecological factors according to Sustainable Industry 4.0, as well as strategic objectives (see Table 4). The first is a cluster of "sustainable friendly" businesses, i.e., conscientious food companies concerned about the growth of sustainability factors (Lachova, 2021). This group consists of 113 companies (43% of the sample set) according to the K-middle procedure. Of all the sustainability factors, ecological ones (0.642) play the most prominent role in the long-term strategic goals of the companies. In terms of business plans, this involves promoting and investing in renewable energies, as well as the use of biodegradable materials (packaging). In addition, the evolution of social factors (0.577) is seen as significant, i.e., the acquisition of new skills by employees.

Tab. 4 - Food company clusters according to sustainability factors Source: own research

	Clusters			ANOVA
	Sustainability friendly	Sustainability neutral	Sustainability avoiders	F-value
Business performance	0.256	-0.098	-1.919	47.525
Economic factor	0.475	-0.235	-2.666	100.674
Social factor	0.577	-0.369	-1.789	74.558
Ecological factor	0.642	-0.364	-2.785	135.585
Strategic goals	0.420	-0.282	-1.066	34.502
Total	113	138	8	

The algorithm classified 53% of the respondents to be in the second cluster, i.e., "sustainability neutral." The "sustainability avoiding" cluster includes companies with below-average business performance (-1.919). In other words, they pay little or no attention to sustainability factors, as they see the potential for increasing business performance in developing other areas. This implies that recycling and supporting the green economy are not addressed. The K-means procedure classified only eight companies as being sustainability avoiders, which is not even half a percent of the sample set. Table 4 indicates which variable gives the best distinction between the clusters. According to the F-value, the ecological factor (135.585) has the greatest impact on the determination of the clusters. In the case of Pearson's Chi-square test, the value is 19.185, with a significance level of 0.259. This means that the clustering of the sectors within the industry cannot be clearly established. For example, sustainability enthusiasts may be engaged in meat or feed processing. Similarly, the ownership structure of the company ($p = 0.602$), its legal form ($p = 0.166$), the number of employees ($p = 0.632$), net sales ($p = 0.709$), business activity ($p = 0.096$) and the three clusters formed significant relationships. The determination of the 3 clusters by county explores which types of companies are in the majority in each area. On the basis of the Pearson's Chi-square value of 65.293 and its low level of significance (p 0.001), the null hypothesis can be rejected, i.e., there is no relationship between the variables. The findings also show that companies that value sustainability are concentrated in Budapest (26.5%) and the counties of Pest (12.4%), Szabolcs-Szatmár-Bereg (17.7%), and Heves (13.3%). Sustainability-friendly clusters are particularly prevalent in the counties of Borsod-Abaj-Zemplén, Fejér, and Szabolcs-Szatmár-Bereg. In the sustainability-neutral cluster, 42% of respondents do business in Budapest and the county of Pest, with 15.2% doing likewise in the county of Heves. In the county of Bács-Kiskun, 68.2% of companies are characterised as being sustainability-neutral, as are companies in the counties of Baranya, Csongrád and Jász-Nagykun-Szolnok, and Komárom-Esztergom. Out of the eight companies in the "sustainability avoider" cluster, three companies do business in the county of Hajdú-Bihar, two in Heves, two in Bács-Kiskun, and one in Budapest. Investing in innovation tools that take sustainability into account is not amongst the strategic goals of these below-average performing companies (World Economic Forum, 2016).

4.3. Partial least squares path modelling outcomes and hypotheses testing

Estimation of external and internal model

By applying the Partial Least Squares Path Modelling approach (PLS-SEM), the Composite Reliability (CR) index was created. In this way, the factor weight values supplied were also taken into consideration. The acceptable value range should be more than 0.7. The model achieves these estimated values, with the composite reliability index outperforming Cronbach's alpha index for all factors. The AVE value specifies how well the manifest variables' variation is preserved by the latent variable. The AVE value should be as high as possible. A score of 0.6, i.e., 60% of the change in business performance, is considered very high in terms of business performance based on the input outcomes of Industry 4.0 tools and Sustainable Industry 4.0 (see Table 5).

Tab. 5 - Cronbach's alpha, CR, and AVE indicator values calculated using Smart PLS software package. Source: own research

Factors	Cronbach's alpha	CR	AVE
Strategic objectives	0.715	0.801	0.369
Obstacles	0.878	0.900	0.452
Supporting aspects	0.785	0.849	0.487
Developments / Investments	0.985	0.987	0.916
Economic factors	0.788	0.846	0.440
Social factors	0.813	0.867	0.528
Ecological factors	0.930	0.944	0.682
Industry 4.0 tools	0.843	0.877	0.418
Profitability indicator	0.790	0.864	0.614
Growth trend indicators	0.824	0.883	0.654

Note: Economic, social, and ecological factors indicated based on Sustainable Industry 4.0; Profitability and growth trend indicators relate to business performance.

The application of the Fornell-Larcker principle shows that the financial risk (0.672) had a maximum value of blockage obstacle. This is evidence that this obstacle is directly associated with this factor. In addition, the model's AVE reveals that the square roots are bigger than the correlation of all reflective constructs in all situations. This result indicates that the requirements of discriminant rationality have been met. The heterotrait-monotrait ratio (HTMT) was employed to measure the correlation matrix of each latent variable. The outcome of the HTMT index shows that each test value is less than 0.9 in those cases involving discriminant validity. To measure the multicollinearity of the variables, the Variance Inflation Factor (VIF) was used. The biodegradable materials indicator value of 4.012 of usage (FI04) was disregarded. Nevertheless, the exogenous latent variables achieve the applicable threshold level of 3.3, which was set by Diamantopoulos and Siguaw (2006). On the other hand, no multicollinearity was found for the exogenous variables, which ranged from 1.163 to 2.792, with the only exception being the FIO4 indicator. The rest of the model is acceptable. The data used for this study are also eligible for model analyses based on prior studies for determining Cronbach's alpha index, CR, AVE, HTMT, and VIF. Moreover, a five-step process was used to evaluate the constructed model, which included calculating predictive importance (Q2), impact magnitude (f2), and path model coefficients.

The Goodness of Fit (GoF) index is measured by using the mean variance and the mean R2. The model fit goodness index is 0.571 x 0.269 = 0.154. This study meets the requirements for goodness of fit because the value exceeds the minimum criterion (0.10). When analysing predictive relevance (Q2), the value of Q2 was always greater than zero, indicating that the study model is predictive. The model is acceptable, with a predictive relevance of 0.410, and in terms of barriers, a value of 0.267. With regard to strategic goals, the relevant values for Industry 4.0 assets and business performance were 0.262 and 0.178, respectively.

Determination of the direct and indirect impacts of the model

Table 6 summarises the results of the direct effect of bootstrapping.

Tab. 6 - Internal model – bootstrapping results: direct effect. Source: own research

Routes	Direct effect coefficient	Sample average	t-statistic value	p-value
Obstacles → Developments / investments	-0.145	-0.144	2.009	0.045
Obstacles → Strategic goals	0.033	0.038	0.556	0.579
Developments / investments → Industry 4.0 assets	0.112	0.109	2.036	0.042
Sustainable Industry 4.0 → Industry 4.0 tools	0.433	0.436	6.981	0.000
Sustainable Industry 4.0 → Business performance	0.340	0.343	3.657	0.000
Industry 4.0 Tools → Business performance	0.187	0.190	2.054	0.040
Strategic goals → Developments / investments	0.156	0.158	1.898	0.058
Supporting factors → Trends regarding developments / investments	0.032	0.038	0.379	0.705
Supporting factors → Strategic goals	0.545	0.560	10.501	0.000

Based on the outcomes, the following can be written about how Industry 4.0 tools affect the model and business performance:

Strategic goals = 0.545 x supporting factors

Supporting factors have a direct, significant impact on strategic goals.

Trends regarding developments/investments = -0.145 x obstacles + 0.156 x strategic goals

The negative sign of the impeding variables suggests that they negative impact the trajectory of innovations and investments (-0.145). If there are additional restrictions, companies will invest less in new technical tools. Obstacles have a direct effect on developments but not on strategic goals (p = 0.579). A company's strategic goals have an effect on innovations and investments.

Industry 4.0 tools = 0.112 x trends regarding developments/investments + 0.433 x sustainable factors

Investments and innovations have a direct influence on the adoption of Industry 4.0 tools, as evidenced by the direct effect coefficient of 0.112. This shows that if a food company wants to expand in a given county, it will almost certainly invest in one or more Industry 4.0 tools. Industry 4.0's economic, social and environmental dimensions are all intertwined with new technical instruments and have a direct influence on business performance.

Business performance = 0.340 x sustainable factors + 0.187 x Industry 4.0 tools

Industry 4.0 tools clearly have a positive coordinate effect on business performance. The more Industry 4.0 tools a company applies, the more advanced the commercial execution of its activities becomes. Supportability factors have a bigger influence on commercial activities than Industry 4.0 tools. By inference, supporting factors are associated with improvements and business performance (p=0.13).

Explication of model's outcomes

Based on the bootstrapping outcomes, the impact of the supporting factors on developments and investments (coefficient=0.032; p-value=0.705) and the impact of weaknesses on strategic plans (coefficient=0.033; p-value=0.579) were used as two possible ways to structure the path model where significant relationships could not be identified.

The model's components, as well as the direct and indirect impacts between the factors, and after the removal of the relationships between the obstacles and strategic goals and between supporting factors and the trends regarding developments/investments, are illustrated in Figure 3.

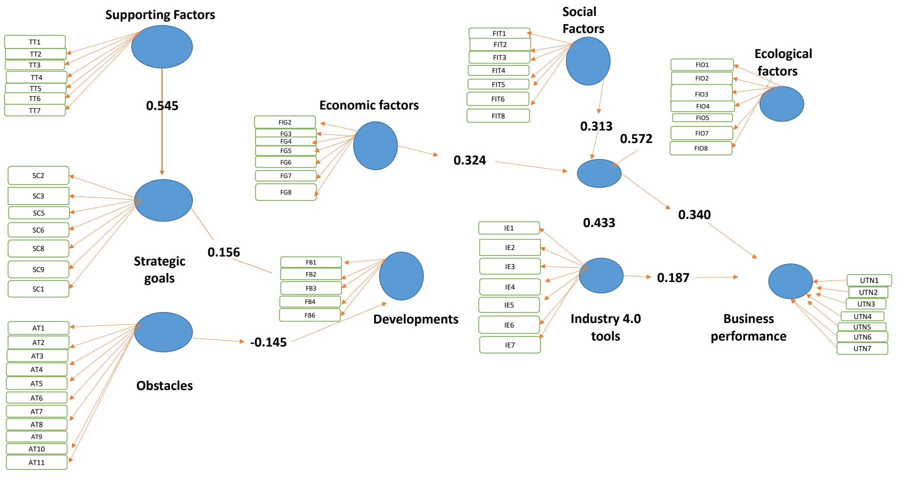


Fig. 3 – Model showing direct and indirect impacts. Source: own research

As a result, supporting variables have a significant impact on strategic goals while also having an indirect impact on business development and investment. Impediments stifle growth; the more obstacles that appear, the fewer new advances will emerge. The most significant barrier preventing organisations from financing new technologies is the high costs associated with them, as well as a lack of internal resources.

For example, a lack of skilled workers should be addressed as an obstacle because it has a substantial impact on investment growth. Additionally, sustainability (economic, social, and environmental issues) has a considerable and noteworthy influence on the implementation of Industry 4.0 tools. In other words, if a food company intends to attach more importance to the effect of its goods on the environment, it will use innovative machines to lessen the company's environmental impact.

Based on the results of this study, under ecological factors, more than 67% of companies support the assumption that new technologies will increase electronic data storage and provide opportunities to reuse products, thereby reducing deforestation (see Figure 4). Likewise, a significant proportion of respondents agreed that the use of renewable energies will increase but disagreed about declining energy costs, with 21% of respondents stating that new technologies will not reduce energy costs.

Most of the responses on the production of biodegradable materials (190 responses) related to the fact that companies are now able to produce products using new technologies that do not pollute the environment and pack them using degradable materials. They clearly believe that the green agenda is supported by new technologies. Innovative methods can be integrated to ensure that factories can use waste to feed their energy systems instead of exacerbating deforestation (Gavurova et al., 2017a; Wohlfahrt et al., 2019; Chen et al., 2020; Metzker et al., 2021).

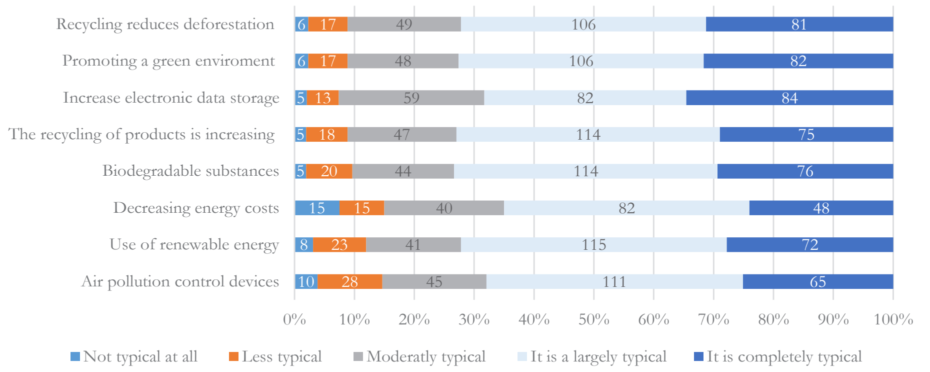


Fig. 4 - Ecological factors of Sustainable Industry 4.0. Source: own research

Graetz and Michaels (2015) examined 17 nations to see how the usage of industrial robots affects economic and productivity growth. This was set against the backdrop that companies set long-term goals from both an economic and a social point of view and think that Industry 4.0 tools can help them to achieve such goals. The findings suggested an increase in economic inequality, with which almost all respondents disagreed. As a result, while the deployment of Industry 4.0 technologies does not dramatically increase economic disparities, it does have a significant impact on a company's competitiveness. The statement that new technologies minimise the occurrence of defects and result in the manufacture of higher quality products was accepted as true by 81% of the study's respondents. Without a doubt, investment assistance and tax incentives have an impact on the adoption of new technologies, as do regulatory laws on the implementation of Industry 4.0 tools within a business. As demonstrated in Figure 5, Industry 4.0 tools have a variety of social implications.

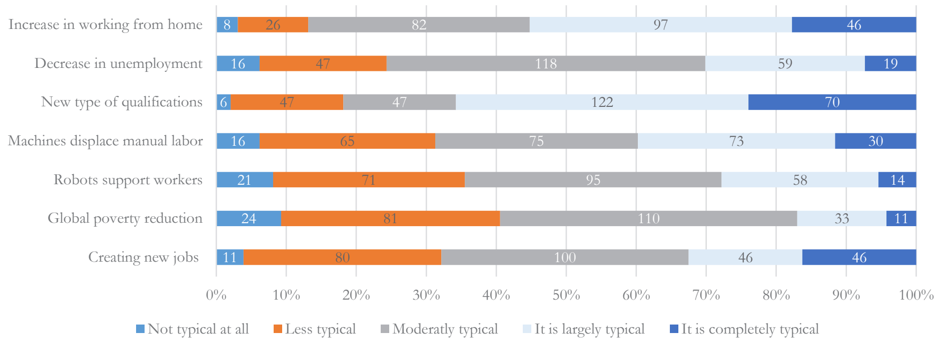


Fig. 5 - Social factors of Sustainable Industry 4.0. Source: own research

It has been found that working from home will intensify. This finding is supported by Ahn and Kim (2017) who found that working from home provides flexibility and reduces pollution. Neutral responses were given to reducing unemployment and global poverty.

It can be stated that new types of qualifications will be needed, creating new jobs. Although machines displace traditional, manual labour, they are designed to support workers by taking over monotonous, thoughtless tasks. The responses from the companies back this up, with 57% stating that they believed this was the case. Bonin et al. (2015) and Mira and Breda (2021) also agree with this assertion, stating that the emergence and proliferation of Industry 4.0 technologies will result in the creation of new jobs. In our model, we looked at the effect of each latent variable on both the utilisation of Industry 4.0 tools and company performance. It was found that Industry 4.0 technical instruments have a mainly robust, positive and important impact on business performance based on the path model (Popp, et al.,2018). This direct impact is evidence that using new technologies helps to enhance business performance (Nagy, 2019). This result confirms H4, whereby new technologies that are consistent with Industry 4.0 tools not only influence sustainability but also the detection of risks, which in turn can have a substantial impact on a company's strategic choices and future investments.

IPMA of sustainability factors and business performance

To build on the study's conclusions, an Importance-Performance Matrix Analysis (IPMA) was carried out to assess business performance. The goal was to find historical variables that are moderately significant to company efficiency, that is, variables that have a large impact but a low factor value. After the IPMA analysis for each indicator was standardised, sustainability was found to have the largest overall impact on business performance compared to the other structures (see Figure 6).

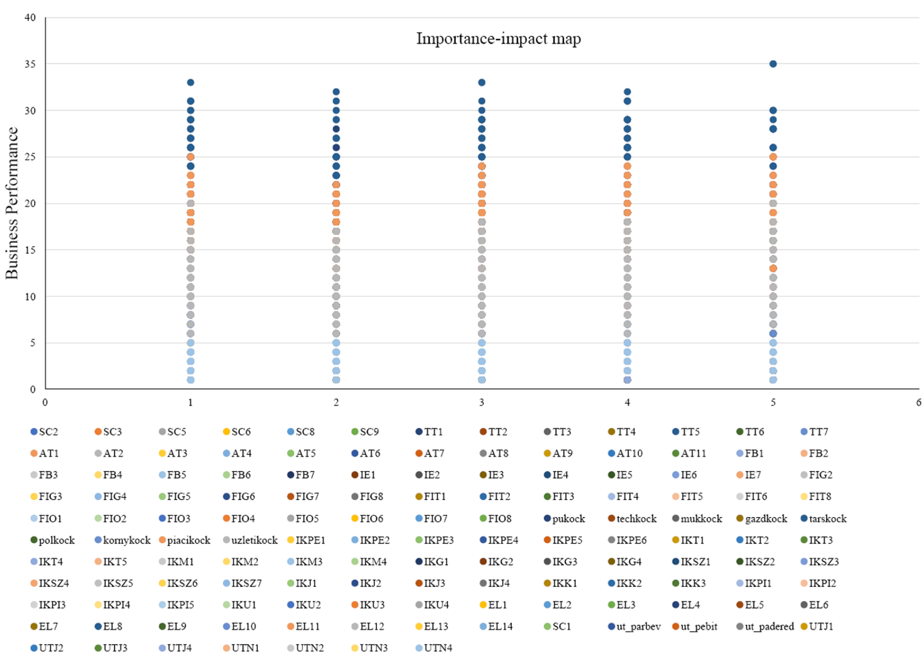


Fig 6. Importance-performance impact map. Source: own research

The indicators "use of renewable energy (solar cells)" (FIO2) and "product recycling" (FIO5) have a significant impact on the sustainability criteria's ecological component.

Industry 4.0 includes machine-to-machine communication (IE4), big data real-time data evaluation (IE3), robotics (IE1), and sensor technologies (IE6). Overall, environmental aspects have a substantial effect on the use of Industry 4.0 tools. As a result, companies should assess and improve in this area. They should focus on, for example, using air pollution control devices, biodegradable packing materials, and obtaining the appropriate tools and equipment. Beyond this, on decreasing errors and boosting profitability within the context of environmental considerations when it comes to business performance.

5. CONCLUSION

The study's main goal was to determine the development plans of Hungarian food companies within the context of the implementation of Industry 4.0 technologies, sustainability and company performance. With this in mind, this study examines the enabling variables and impediments to Hungarian food companies by presenting the benefits and drawbacks of Industry 4.0 tools in terms of company efficiency and profitability. Sustainability, from this point of view, improves business performance, success and value, as well as reduces the consumption of resources, thereby benefiting society as a whole.

The significance of the coefficients and t-statistics for all paths were computed on the basis of bootstrap sampling (5,000 subsamples). Sustainability considerations, including ecological factors, such as product recycling and the use of renewable energies, were determined to be the most significant influences on business performance based on the IPMA analysis of business efficiency and individual aspects thereof (Ślusarczyk et al., 2020). Industry 4.0 technologies have a significant impact on business performance in areas such as sensor technology and machine development, as well as the growth of machine-to-machine communication, data analysis and industrial competitiveness.

According to the empirical tests, no significant relationship exists between the location of food companies and sustainability clusters. However, the high cost of technology, a lack of internal resources, and a scarcity of qualified workers are all impeding the expansion of Industry 4.0. In addition, the range of innovative technologies and their application thereof has a large, positive and important effect on the business performance of food companies, with environmental concerns having the greatest impact. Based on the findings, H1 was refuted, while H2, H3, and H4 were confirmed.

Our findings have crucial theoretical and practical implications for policy makers, public authorities and other stakeholders. Firstly, the study provides empirical support for adopting approaches based on the circular economy, cleaner production and Industry 4.0, with companies able to significantly improve their performance based on sustainability. Secondly, Industry 4.0 technologies provide cleaner production and innovative approaches that are increasingly gaining traction because of their contribution to sustainable performance. Finally, but no less importantly, Sustainable Industry 4.0 and business performance differ from country to country and according to the structure of their competitiveness. In future research, different data sets and combinations of data gathered over a longer period of time, as well as the application of new statistical techniques, may be beneficial to many countries in terms of the potential positive influence such analyses may have on the international dimensions of companies.

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