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ANALYZING THE EFFICIENCY OF DIGITALIZATION IN SMALL AND MEDIUM-SIZED ENTERPRISES ACROSS EU COUNTRIES USING DEA MODELS

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ABSTRACT

The process of digitizing businesses involves ongoing investments and additional costs, leading to the inevitable inquiry into the economic impact of digital transformation. Specifically, it's important to evaluate how this process contributes to the economic growth of nations. The article introduces a method for creating a ranking of European countries according to the economic benefits derived from digitalizing businesses of different scales. To achieve this, DEA models were developed to measure the effectiveness of digital adoption by small and medium-sized enterprises and larger corporations. For input variables, we selected metrics that reflect the extent of business digitalization, specifically, the proportion of SMEs (small and medium-sized enterprises) with a high digital intensity index (DII), the percentage of SMEs utilizing cloud technologies, and the contribution of SME turnover to the overall e-commerce turnover. The output variables chosen were metrics indicative of a country's economic health: GDP per capita, the ratio of exports to GDP, and the international investment position. The evidence demonstrates that due to significant differences in size, economic advancement, and digitalization levels among EU countries, the VRS model more adeptly accommodates these disparities. This approach permits the evaluation of each country's performance based on its unique situation and potential for development, without consideration of its economic magnitude. In 2022, Denmark, the Netherlands, Sweden, Finland, Malta, and Belgium emerged as the frontrunners in digital intensity among SMEs, with nearly 40% of businesses exhibiting a high degree of digital engagement. Among these leaders, only Malta and the Netherlands achieved the highest efficiency in leveraging digitalization for economic growth, as determined by the VRS model that considers variable returns to scale. It was shown, that the economic effect of digital transformation on large enterprises in EU countries is more substantial than on small and medium-sized enterprises.

Keywords: digitalization, SME, EU countries, digital intensity index, DEA model, VRS, CRS, economic growth, efficiency, performance, GDP per capita

JEL Classification: C67, L25, L11, F63

INTRODUCTION

Digital transformation of SMEs reduces operating costs and improves operational efficiency, which in turn promotes business transparency and better access to external finance. The COVID-19 crisis has prompted significant investment in digital technology to protect the health of customers and employees. As noted by Kane et al. (2021), these digital business tools include consumer-facing applications such as grocery and food delivery services, e-commerce applications and applications such as video conferencing, which have penetrated the world of consumers, businesses and non-profit organizations forever. The COVID-19 pandemic has demonstrated a clear link between business digitalization and its survival, which has significantly accelerated the pace of digital transformation, and today the reliability and sustainability of the SME largely depend on whether SMEs can change their relationships with customers and find the necessary digital solutions and automated business processes (Justice C. & Fersht P., 2021). The importance of digitalizing the company's business processes was noted even before the

pandemic by the executive head of Cisco Systems, John Chambers, who noted that at least 40% of all companies will die in the next 10 years... if they do not understand how to change their entire company to adapt new one's technology (LUISS Guido Carli University, 2019). E-commerce has become an integral part of business in the modern world for decades and has received a very powerful acceleration in its development during the coronavirus period. However, the process of business digitalization requires constant investment and other expenses and, naturally, the question arises of assessing the economic effect of the digital transformation process itself, namely, how it affects the economic development of countries.

LITERATURE REVIEW

A significant number of research and scholarly articles focus on examining how digital transformation affects the operational processes of small and medium-sized enterprises (SMEs). This research area is crucial as it sheds light on the way digital technologies can revolutionize the way SMEs operate, potentially boosting their efficiency, market presence, and capacity for innovation. Research Beck et al. (2005) conducts a comparative review, assessing the adoption and application of information technologies and e-commerce within manufacturing SMEs across the United States and Europe. Wang et al. (2020) propose a hybrid approach, which involves forecasting and evaluating the effectiveness of e-commerce by combining the Gray model and the DEA model. The analysis found that in the US, the best-performing e-commerce market in recent years is eBay, with Best Buy and Lowe's ranking second and third, respectively. Beck et al. (2005) note that most companies have made a significant step forward in technological development and the determining factor in the growth of their efficiency is precisely technological efficiency.

The research European Commission (2021) is devoted to the assessment of the effectiveness of the use of various instruments of state support for the implementation of innovations by SMEs, where it is noted that the main problem in such an assessment is how to interpret the results obtained in various studies. Although some positive impact of all types of instruments has been shown, accurate assessment of such impact on innovation outcomes often remains problematic. The authors argue that the reason for this is the existence of a large number of factors that affect the effectiveness of instruments, starting with the development and implementation of the instrument at a specific regional, national or international level.

DEA models are the most popular tool for evaluating performance at the micro and macro levels. İnel (2019) and Kaygisiz (2022) proposed approaches to ranking countries regarding the effectiveness of digital transformation using the DEA methodology. Hussain et al. (2022) with the help of DEA models evaluated the effectiveness of the e-commerce use, namely, its impact on the efficiency of small and medium-sized enterprises. The results showed that the relationship between e-commerce use and firm performance is positively significant. The DEA model was also used Ma'ruf et al. (2018) and Im & Cho (2021) to analyze the efficiency of SMEs in Indonesia and South Korea, respectively. Dobrovič et al. (2021) conducted a study of the effectiveness of Slovakian SMEs in the tourism sector on the basis of the DEA methodology.

The Digital Economy and Society Index (DESI) is most often used to assess the level of national economies digitization. Thus, Bánhidi & Dobos (2023) proposed a ranking of digital technologies implementation in 28 countries of the European Union based on the DESI index and DEA models. In the majority of articles devoted to the problem of digitalization of business and other aspects of economic activity, it is noted that the countries of Northern Europe have achieved the greatest success in this area (e.g., Bánhidi & Dobos (2023)). Thus, according to Krejnus et al. (2023), four of the seven countries of Northern Europe are the most effective in the field of e-Government.

Skvarciany et al. (2023) when measuring the performance of the digital economy in EU countries, the Digital Economy and Society Index (DESI) was taken as the input data and the Sustainable Development Goals Index (SDGI) as the input variable. The results of the efficiency assessment using the DEA methodology showed that Bulgaria, Italy and Romania are the most effective digital economies in terms of human capital formation (Skvarciany et al., 2023). Kaygisiz (2022) used the input-oriented Cooper and Rhodes DEA (CCR-O) model to determine the digital intensity of European countries.

Although there is a significant number of scientific studies addressing the effectiveness of digitalizing small and medium-sized enterprises (SMEs) business processes, the majority of them primarily examine the adoption rate of digital technologies in the global business landscape. However, insufficient attention is paid to the problems of studying the economic effect of the implementation of digital transformation at enterprises, depending on their size.

Thus, it is crucial to evaluate, not in absolute but in relative terms, which types of companies' digitalization contribute most significantly to the economic advancement of nations. In other words, it will allow ranking EU companies of different sizes depending on the effectiveness of spending on their digital transformation.

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AIMS AND OBJECTIVES

In this study, we aimed to analyze the effectiveness of the digitalization process in SMEs of the EU countries, namely, to estimate the economic effect at the macro level from the costs of digital business transformation of this group of enterprises and compare them with large companies.

Objectives of the article are the following:

- to build input-oriented DEA models for evaluating the efficiency of digitalization of SMEs and large companies;
- to determine the input and output variables of the models, which would fully characterize the scale of digitalization and the level of economic development in the EU countries, respectively;
- to analyze which type of DEA model is better suited to solving our problem - with variable or constant return;
- on the basis of the obtained results, analyze how the digitalization of enterprises of different sizes affects the economic development of EU countries.

METHODS

To solve these problems DEA (Data Envelopment Analysis) models were chosen to evaluate the relative efficiency of countries, comparing them with the best practices in the group. To form a more complete picture of business processes' digitalization in the EU, we compared the effectiveness of SMEs and large companies' digitalization. In the European Union, enterprises with 10 to 250 employees are considered small and medium-sized enterprises, and Enterprises that have over 250 employees are classified as large enterprises.

As input variables, we used indicators that characterize the level of digitalizing of business, namely, the share of SMEs with a high level of digital intensity (DII, digital intensity indicator), the share of SMEs that use cloud technologies and the share of SME turnover in the total e-commerce turnover. The output variables were indicators that determine the level of economic development of the country: GDP per capita, share of exports in GDP and international investment position (Table 1).

Table 1. Input and output variables of DEA model 1 (for SMEs).

Input		Output	
DIsme	Share of SMEs with a high level of digital intensity DII (digital intensity index)	GDP_cap	GDP per capita (euro)
Cloudsme	Share of SMEs using cloud technologies	Export	Exports (% of GDP)
TURNsme	The share of SMEs turnover in E-commerce from the total turnover	Net_invest	International investment position (% of GDP)

To compare SMEs and large companies, we also built a DEA model with similar output variables and input variables that characterize the level of digital technology usage by large companies (Table 2).

Table 2. Input and output variables of DEA model 2 (for large companies).

Input		Output	
DIl	Share of large companies with a high level of digital intensity DII (digital intensity index)	GDP_cap	GDP per capita (euro)
Cloudl	Share of large companies that use cloud technologies	Export	Exports (% of GDP)
TURNl	The share of large companies' turnover in E-commerce from the total turnover	Net_invest	International investment position (% of GDP)

The choice of the number of input and output variables in DEA models is key to accurately assessing DMU performance. When determining the optimal number of input and output indicators, the technique proposed by V. Cooper is often used (Cooper et al., 2006):

$$k \geq max\{wm, 3(w+m)\} \quad (1)$$

where k is the number of DMU (decision-making unit), w and m are the number of input and output variables, respectively.

The main difference between the CRS (Constant Returns to Scale) and VRS (Variable Returns to Scale) models is the assumption regarding the scale effect. The CRS approach is used when it is assumed that DMUs operate at the best scale of production. In other words, if the input costs increase n times, the results will also increase n times. The CRS model is useful for analyzing the performance of DMUs operating at scales considered optimal.

In contrast, the VRS model assumes that DMUs may not operate at optimal production scales. This means that a change in the scale of production may lead to a disproportionate change in output. For example, doubling inputs may lead to an increase in outputs, but not necessarily twice (Elangovan et al., 2022). The VRS model is useful for evaluating the performance of DMUs that may operate at scales that are not optimal. The key difference is that the CRS model measures overall efficiency by taking into account scale efficiency, while the VRS model measures pure technical efficiency by ignoring the effects of scale of production. This means that VRS can identify DMUs that are efficient in terms of resource utilization, even if they are not operating at the most efficient scale.

Input-oriented DEA models quantify the necessary reduction in input variables (reduction in SME digitization costs) that will allow the DMU to become efficient with fixed inputs. Whereas output-oriented models quantify the necessary increase in output parameters (improvement in the country's level of economic development) with fixed input resources. In our opinion, the results obtained in input-oriented DEA models in our case are subject to a more understandable economic interpretation with such a set of input and output variables and allow us to answer the key question of this study, namely, to evaluate the economic effect of the digital transformation of business processes of European companies. Subsequently, we implemented only input-oriented DEA models. The input-oriented CCR model proposed by A. Charnes, W. Cooper and E. Rhodes in general will look as follows (Charnes et al., 1978):

$$\min_{\theta,\lambda} \theta \quad (2)$$

$$\begin{cases} \theta x_i - X\lambda \geq 0 \\ Y\lambda \geq y_i \\ \lambda \geq 0 \end{cases} \quad (3)$$

where θ is the efficiency of DMU; X is a vector of input variables; Y is a vector of output variables; λ is a vector of weights; x_i is a vector of input variables of the ith DMU; u_i is the vector of output variables of the ith DMU.

To take into account variable returns to scale (VRS), a condition (4) is added to the model (2)-(3) that guarantees the equality of the sum of weights:

$$\sum_i \lambda_i = 1 \quad (4)$$

The built DEA models (model 1 - for SMEs, model 2 - for large enterprises) allow us to evaluate the efficiency of SMEs digitalization, or, in other words, the efficiency of investments in the process of SMEs digitalization in the context of the economic development of European countries. We carried out efficiency assessments based on DEA models using the Efficiency Measurement System (EMS) package.

RESULTS

Today's consumers expect a high level of service, personalization and convenience made possible by digital technologies. Online platforms, mobile applications, artificial intelligence and big data enable companies to better understand and meet the needs of their customers. European regulatory authorities often require greater transparency and compliance with various standards, which can be provided thanks to digital solutions. For example, GDPR (General Data Protection Regulation) requires companies to more strictly manage personal data. As the director of the economic department of the European Investment Bank, Deborah Revoltella noted, the European Union is reducing the lag in the digital sphere compared to the United States. More than half of European companies have responded to the challenges of the pandemic by investing in digitalization, which allows them to quickly approach the level of American firms in using the latest digital technologies. However, Europe still lags behind in digital innovation and risks becoming dependent on a few key technologies. Digitization increases companies' ability to withstand economic shocks and climate change, helping European firms

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to adapt during various crises. Digital companies tend to be more efficient and productive than non-digital ones. They are also more likely to engage in international trade and invest in addressing both physical and transition risks associated with climate change (European Investment Bank, 2023).

Most studies devoted to this issue analyze the effectiveness of exactly the process of digitalization of SMEs, but we made an attempt to assess the economic effect of the use of digital technologies by small and medium-sized businesses from the standpoint of the economic development of national economies. To a certain extent, we tried to assess the return on investment in the digitalization of SMEs.

The digital intensity indicator DII (Digital Intensity Index) is calculated based on the values of 12 variables, each of which can give 1 point. DII distinguishes four levels of digital intensity for the analyzed enterprise (Eurostat, 2022):

1. An enterprise with a very low DII has scores between 0 and 3.
2. A low DII company with a score of 4 to 6.
3. A company with a high DII has a score of 7 to 9.
4. An enterprise with a very high DII has a score of 10 to 12.

Subsequently, as an input variable, we used the share of SMEs with high DII, that is, those with scores from 7 to 9 (Figure 1). We selected companies with high DII because there are most of them and, in our opinion, they best characterize progress in the digitalization of business as a whole.

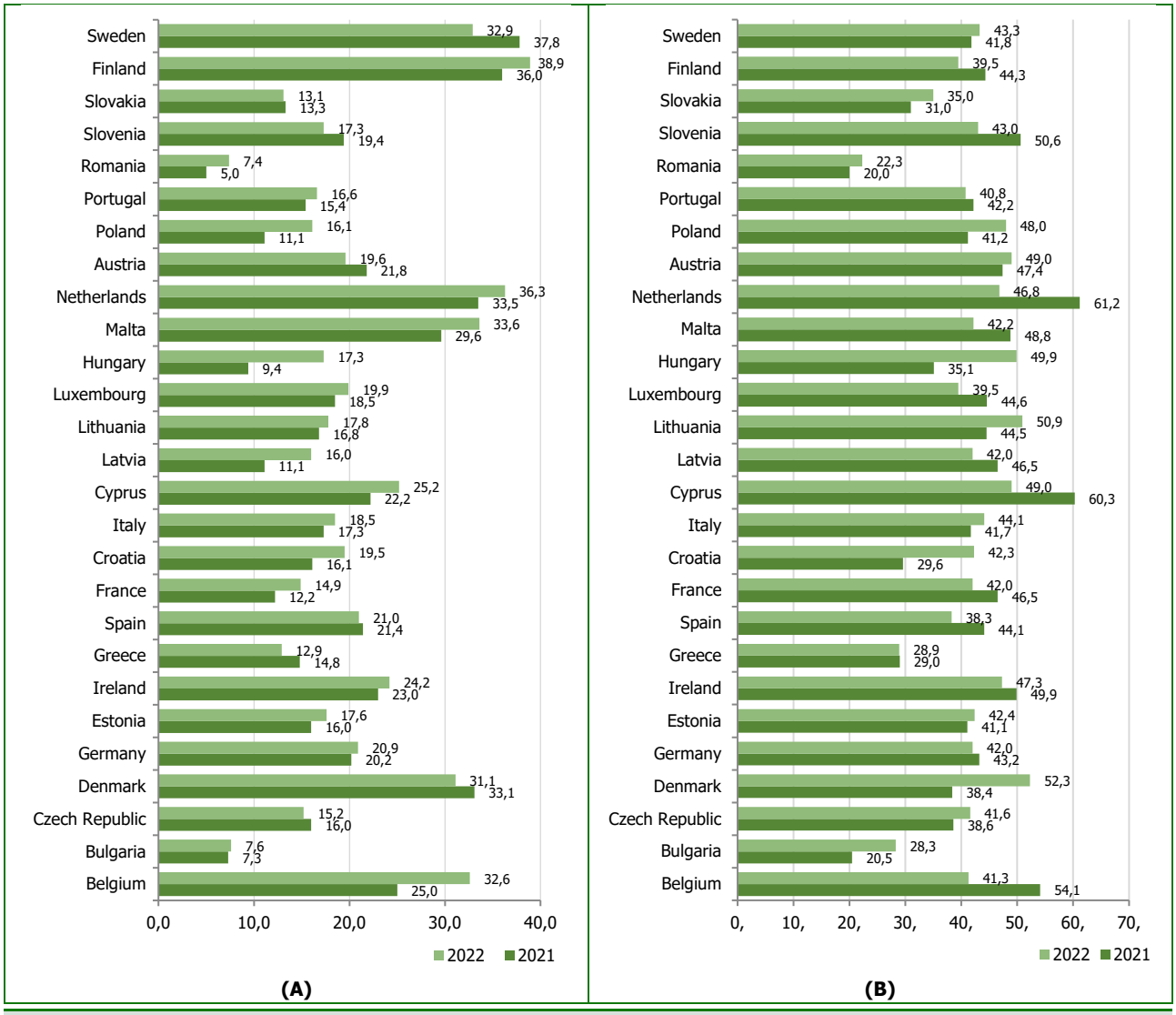

Figure 1. Enterprises with a high level of digital intensity, %. Note: (A) – SMEs, (B) – large enterprises. *(Source: compiled by the authors on the basis of data from Eurostat)*

For constructing a DEA model, we selected indicators related to the growth of e-commerce, given its significance and prominent role in digital transformation. E-commerce enables firms to engage in business activities online, transforming conventional physical operations into digital formats. This means that business operations, from marketing to sales, from customer service to delivery, can be automated and optimized using digital technologies. Ireland is the clear leader in the EU in terms of total e-commerce turnover for both SMEs and large enterprises, while Cyprus has the lowest sales figures (Figure 2).

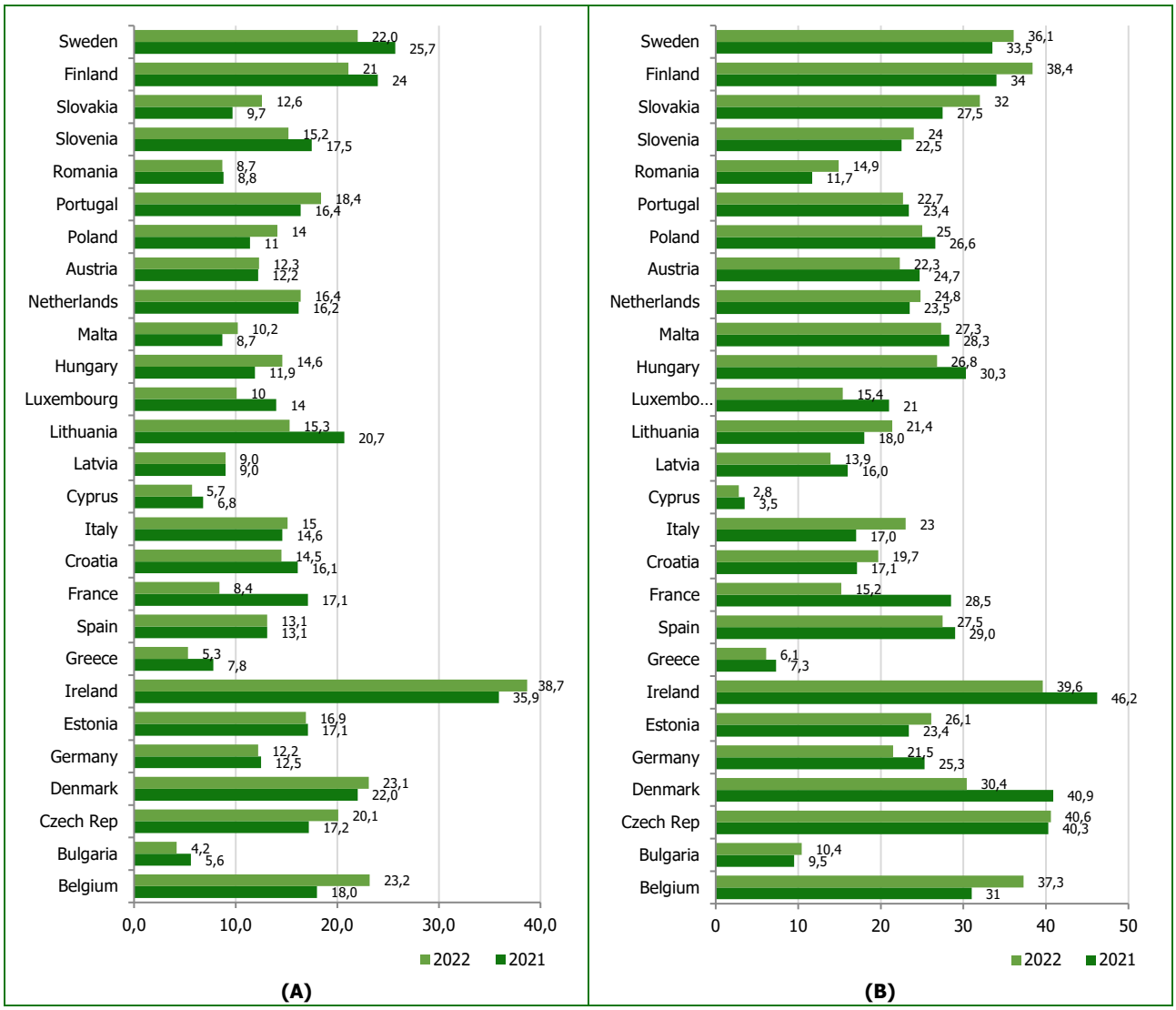

Figure 2. Total turnover of enterprises from e-commerce, percentage of total turnover. Note: (A) – SMEs, (B) – large enterprises. *(Source: compiled by the authors on the basis of data from Eurostat)*

The use of cloud technologies is one of the key indicators of the digitalization of business processes, as it reflects the level of integration of modern technological solutions into the daily activities of the company. Cloud technologies enable businesses to be more flexible, efficient and innovative. Today, SMEs use a variety of cloud services, depending on their needs, namely:

- infrastructure as a service (IaaS). Amazon Web Services (AWS), Microsoft Azure and Google Cloud Platform provide virtual servers, networking components and data storage, allowing SMEs to run their applications and store data without the need to own physical infrastructure;
- platform as a service (PaaS). Heroku, Microsoft Azure App Service, and Google App Engine offer environments for developing, testing, and deploying software, greatly simplifying the application development process;
- software as a service (SaaS). A wide range of business applications, from email (e.g. Google Workspace, Microsoft Office 365) to customer management (CRM) (e.g. Salesforce), project management (e.g. Asana, Trello) and accounting (e.g. QuickBooks, Xero), are available as online services.

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- tools such as Slack, Microsoft Teams and Zoom help companies collaborate effectively in real-time, regardless of their geographic location;
- cloud data storage services. Dropbox, Google Drive and Microsoft OneDrive offer convenient solutions for storing, syncing and sharing files.

The share of large enterprises in EU countries that use cloud technologies is higher compared to SMEs (see Figure 3).

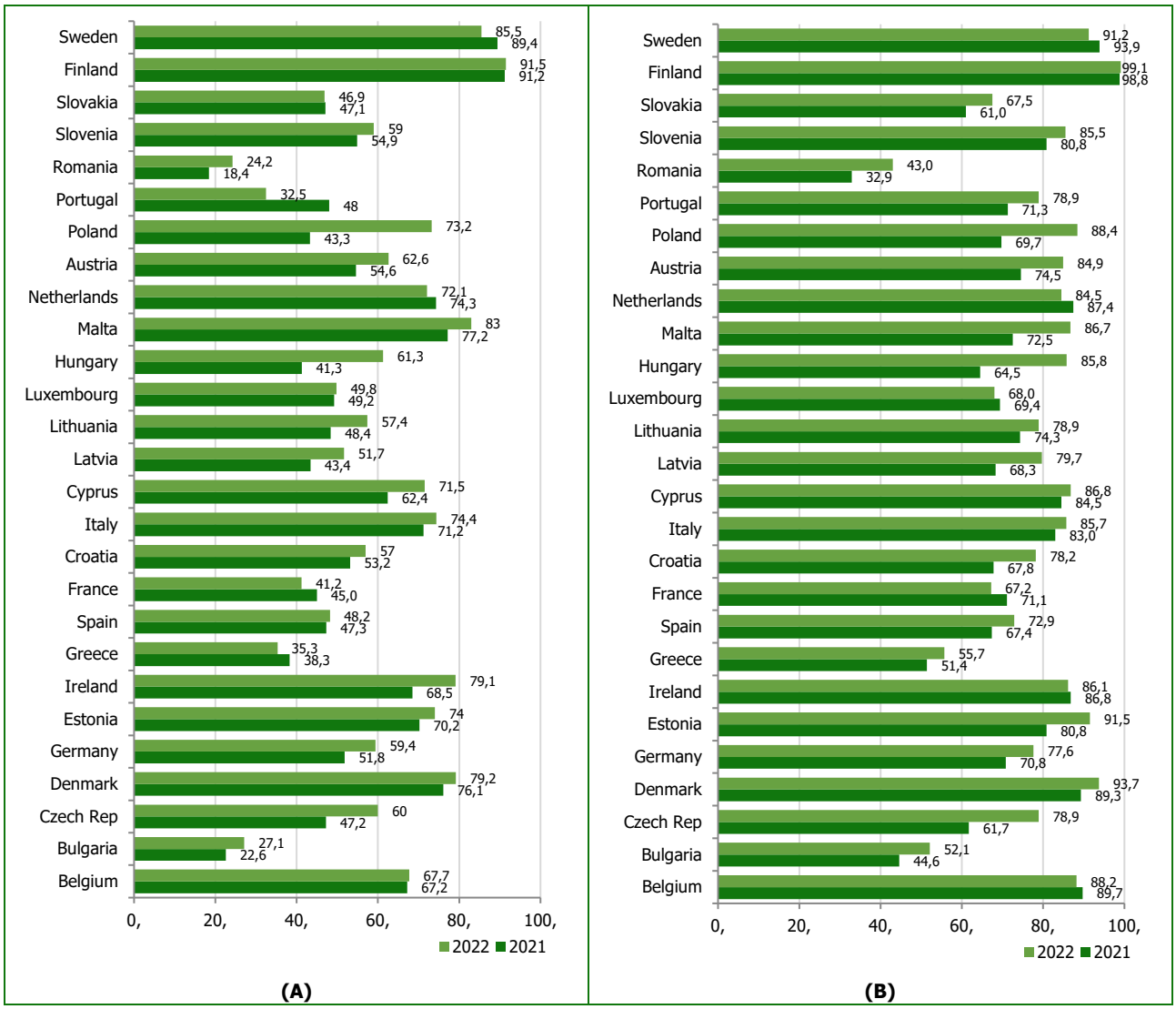

Figure 3. Share of enterprises using cloud technologies. Note: (A) – SMEs, (B) – large enterprises**.** *(Source: compiled by the authors on the basis of data from Eurostat)*

We chose GDP per capita as one of the output variables. As can be seen in Figure 4, Luxembourg and Ireland have the highest GDP per capita, which is often used as one indicator of development, along with other indicators such as the Human Development Index (HDI), which takes into account education, life expectancy and income. GDP per capita allows you to compare the economic level of development of different countries, taking into account their population. This helps to identify countries with high levels of productivity and economic efficiency.

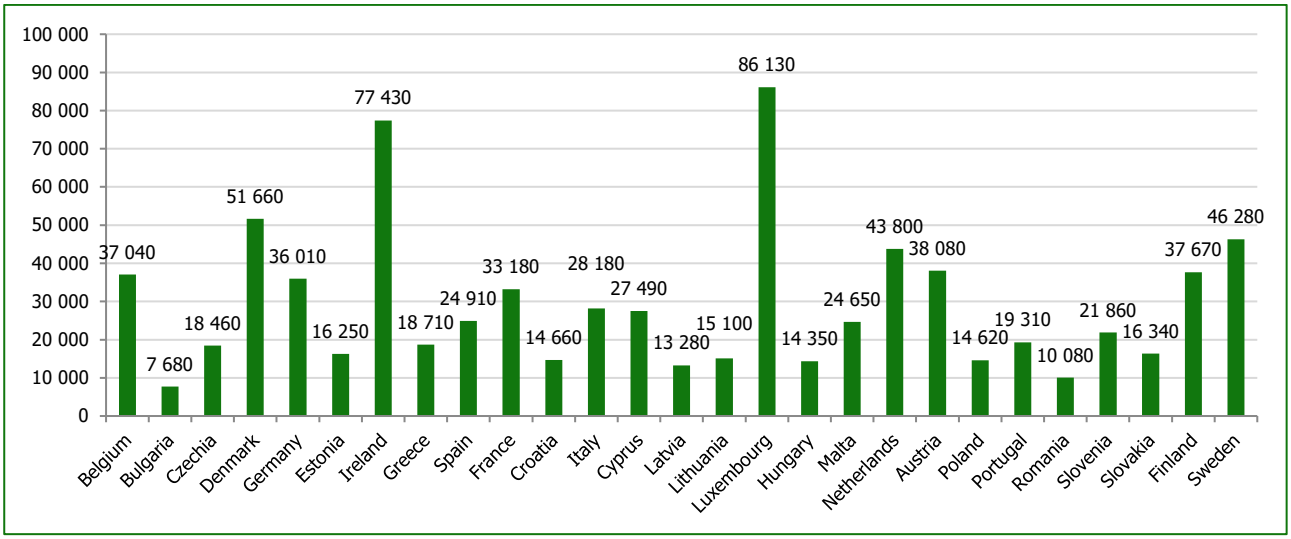

Figure 4. GDP per capita, EUR. *(Source: compiled by the authors on the basis of data from Eurostat)*

The International Investment Position (NIIP) reflects the difference between a country's external financial assets and its external financial liabilities (Figure 5). It is essentially a measure of a country's net foreign assets, indicating whether it is a net lender or borrower to the rest of the world. A positive Net International Investment Position, reflecting a scenario where a nation's overseas assets surpass its foreign obligations, signifies its status as a global net lender. This condition is often interpreted as a sign of economic robustness and stability. On the other hand, a negative Net International Investment Position (NIIP) may indicate a country's potential exposure to risk, particularly if it owes substantial amounts to international lenders. This situation could suggest financial instability or economic weakness. We chose the international investment position as one of the indicators of the economic development of the EU countries since the NIIP is closely related to the country's trade balance. We used this indicator because it was a trade that experienced the most serious transformations in connection with the dynamic processes of economic relations digitalization. A country that consistently has a positive trade balance can accumulate foreign assets, leading to a positive NIIP. In addition, a sustainable level of NIIP is crucial for financial stability. High levels of foreign debt, as indicated by a negative Net International Investment Position (NIIP), might expose an economy to increased risk, especially under adverse financial market conditions that complicate debt repayment. This situation could potentially weaken the country's financial stability.

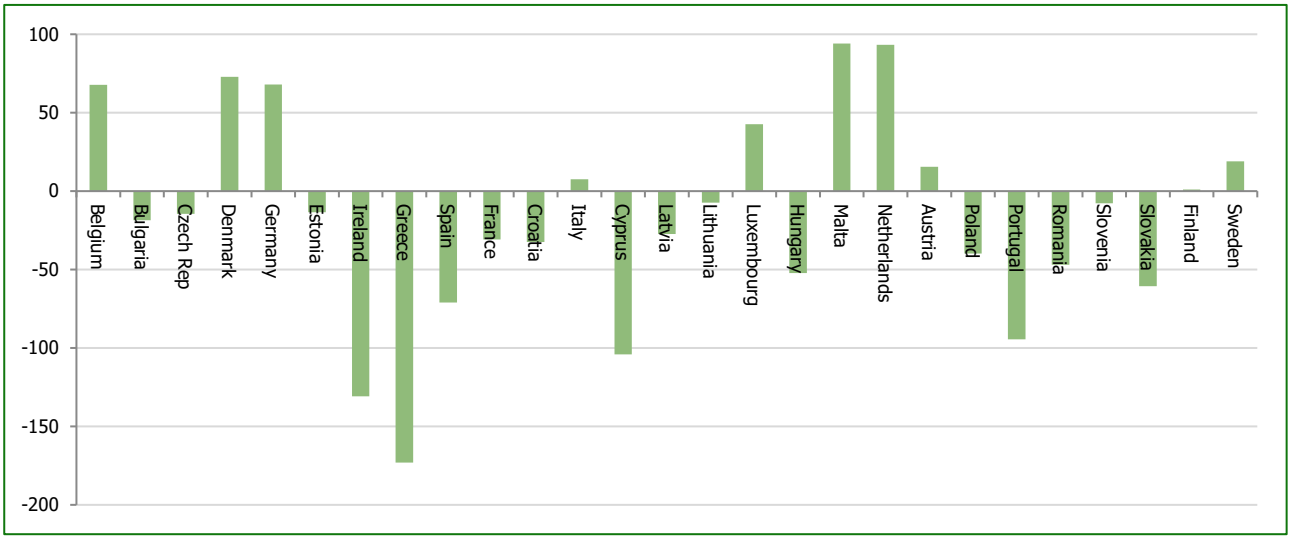

Figure 5. International investment position (NIIP) of EU countries at the end of 2022 as a percentage of GDP. *(Source: compiled by the authors on the basis of data from Eurostat)*

The third variable we included in the input indicators of the DEA model was the share of exports in GDP. This is an important indicator that can reflect some aspects of the country's economic development. Countries that have a high share of exports in various sectors can achieve greater economic stability and less dependence on internal economic fluctuations

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(Ji et al., 2022, Kalaitzi & Chamberlain, 2020). Export of goods has a stronger positive correlation with the growth of GDP, total fixed assets, and productivity in the EU. Conversely, an increase in the export of services shows a stronger positive correlation with employment growth. Furthermore, the proportion of exports, particularly of knowledge-intensive services, relative to GDP, is higher in countries with higher GDP per capita (Bacovic, M., 2021).

The results of efficiency evaluations based on CRS models are presented in Table 3, using the assumption of the existence of variable returns to scale, based on VRS models - in Table 4.

Table 3. Efficiency based on input-oriented CRS models. *(Source: compiled by the authors using EMS package on the basis of data from Eurostat)*

	2021		2022	
	Large enterprises, %	**SME, %**	**Large enterprises, %**	**SME, %**
Belgium	74.76	84.26	82.89	76.62
Bulgaria	63.44	72.98	47.76	85.75
Czech Republic	39.40	39.43	34.38	47.40
Denmark	100.00	77.26	74.68	66.63
Germany	93.03	100.00	100.00	100.00
Estonia	40.87	43.55	37.83	45.91
Ireland	74.35	66.91	75.07	73.93
Greece	52.98	36.44	49.41	44.28
Spain	28.14	29.20	29.83	29.88
France	36.58	56.83	39.02	51.45
Croatia	35.12	26.79	26.16	28.59
Italy	37.95	33.45	29.31	35.19
Cyprus	100.00	79.09	100.00	79.67
Latvia	37.16	50.50	36.13	42.38
Lithuania	42.35	41.37	35.40	45.93
Luxembourg	100.00	100.00	100.00	100.00
Hungary	47.62	73.76	34.21	49.65
Malta	100.00	100.00	100.00	100.00
Netherlands	100.00	97.07	100.00	91.34
Austria	39.88	48.63	35.64	44.89
Poland	29.30	45.11	24.42	36.68
Portugal	22.05	25.07	22.73	35.97
Romania	42.47	70.46	36.05	54.73
Slovenia	36.14	37.39	40.91	51.23
Slovakia	62.15	61.97	53.09	71.46
Finland	43.17	25.01	43.74	23.80
Sweden	55.73	28.75	55.02	36.77
Average value	56.84	57.45	53.47	57.41

Table 4. Efficiency based on input-oriented VRS models. *(Source: compiled by the authors using EMS package on the basis of data from Eurostat)*

	2021		2022	
	Large enterprises, %	**SME, %**	**Large enterprises, %**	**SME, %**
Belgium	80.47	84.81	94.65	80.10
Bulgaria	100.00	100.00	100.00	100.00
Czech Republic	69.80	54.15	62.91	59.60
Denmark	100.00	80.06	77.66	68.73
Germany	100.00	100.00	100.00	100.00
Estonia	57.91	53.76	62.91	51.35
Ireland	80.05	69.33	79.35	76.32
Greece	100.00	84.16	100.00	94.90
Spain	58.71	58.49	66.98	62.03
France	61.52	73.84	81.65	82.11
Croatia	73.31	45.41	63.34	47.85
Italy	79.55	67.00	69.57	59.97
Cyprus	100.00	100.00	100.00	99.82
Latvia	65.25	71.51	71.01	55.02
Lithuania	64.73	56.06	66.90	52.11
Luxembourg	100.00	100.00	100.00	100.00
Hungary	69.48	85.89	58.46	54.94
Malta	100.00	100.00	100.00	100.00
Netherlands	100.00	100.00	100.00	100.00
Austria	73.12	72.90	70.21	68.45
Poland	53.71	65.21	53.88	51.82
Portugal	53.97	49.78	61.16	84.02
Romania	100.00	100.00	100.00	100.00
Slovenia	58.96	49.87	68.34	57.26
Slovakia	81.85	74.57	80.18	77.97
Finland	66.55	36.53	74.92	37.73
Sweden	78.33	42.36	81.35	51.11
Average value	78.79	73.17	79.46	73.08

In the context of the CRS model, efficiency evaluation is based on the premise that countries are able to scale their resources while maintaining efficiency without any losses. Thus, it analyzes how effectively countries use the digitalization of SMEs, which is represented by such input variables as the digital intensity of SMEs, the share of SMEs using cloud technologies and the turnover of SMEs from e-commerce to achieve the output indicators that determine the level of economic development of the country, namely GDP per capita, share of exports in GDP and international investment position. With this approach, Germany, Malta, Luxembourg and the Netherlands turned out to be the most effective in 2021 and 2022, while Finland showed the least efficiency, namely 25.01% and 23.8%. The low rankings of the Scandinavian countries Finland and Sweden are explained by their leading positions in the adoption of digital technologies and significantly lower rankings in economic development indicators, especially with regard to the share of exports in GDP and international investment position.

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Since the constructed models assess the effectiveness of investments in the digital transformation of SMEs and large companies, namely how they affect the macroeconomic indicators of EU countries, in order to obtain high-efficiency values in the country, the ratio of the level of economic development and the level of digitalization must be high. This means that countries with a high level of economic development, but with even higher rated digitalization indicators, will not have high ratings regarding the efficiency of using digitalization, since the economic effect of investments in the digital transformation of their economies will be less. Moreover, countries with low GDP per capita, for example, Bulgaria, but with average SME digitalization rates, quite naturally have higher efficiency in CRS models.

If we take countries with a high level of SME digital intensity that is close to 40%, namely Denmark, Finland, Sweden and the Netherlands, their efficiency in using digitalization will vary significantly because the underlying variables representing the macroeconomic indicators for these countries are different. For example, the level of digitalization of SMEs in Sweden and Finland is significantly higher than the level of their economic development. This imbalance had a negative impact on the rating in both cases: in the CRS and VRS models. The efficiency of digitalization of SMEs in Denmark and the Netherlands is significantly higher in the case of the CRS model - 66.63% and 91.34%, respectively, since there is no such noticeable imbalance.

The maximum efficiency based on VRS models, in addition to Germany, Malta, Netherlands and Luxembourg, was also shown by countries with the lowest macroeconomic indicators - Bulgaria, and Romania. VRS efficiency assesses how effectively countries use their resources given their current level of development and capabilities.

An important question is: which CRS or VRS model gives a more correct assessment of efficiency in our case? VRS efficiency focuses on technical efficiency, allowing opportunities for improvement to be identified regardless of DMU size. VRS is more adaptable to the analysis of DMUs of different sizes because it takes into account the possibility of variable returns to scale, whereas CRS requires the assumption of constant returns to scale for all DMUs. In our opinion, the choice of the VRS model for assessing the efficiency of digitalization of EU countries is more justified because of its ability to better adapt to the diversity and specificity of the member countries, as well as to provide a more accurate and fair analysis of the efficiency of using resources for digital transformation. The VRS score measures how effectively a country uses its digital infrastructure and investments in SME digitalization to achieve economic development and international trade results, regardless of its overall size or economic strength.

DISCUSSION

Digitalization of European business today is no longer just a trend, but a key strategy for ensuring sustainable development, competitiveness and innovativeness of business. However, digitalization is not a one-time process. Maintaining, updating, securing and developing computer systems requires ongoing investment. In this connection, the logical question is about the economic effect of investments in the digital transformation of business in SMEs and large enterprises.

This article stands out by focusing not on the broad theme of economic digitalization, as is common in many DEA methodology-based studies, but on the distinct contribution of SMEs' digitalization to the economic growth of national economies. Furthermore, we developed a DEA model to assess the efficiency of digital transformation in large companies, allowing for a comparative analysis with SMEs. Instead of using the DESI index commonly applied to gauge the level of digitalization in business processes, our study utilized the Digital Intensity Index (DII). The DII's distinct advantage lies in its tailored calculation for businesses of varying sizes, aligning more closely with our research objectives. Moreover, our approach incorporated a broader set of input and output variables, enabling a comprehensive evaluation of the myriad factors influenced by SMEs' digitalization within EU countries.

It should be noted that the results obtained in the article to a certain extent overlap with the results of other studies, namely, countries with a very high level of adoption of digital technologies demonstrated in some places very low efficiency of their use in terms of economic growth. Thus, Esin (2021) showed that developing countries use digitalization more effectively in the context of economic growth and job creation. Esin (2021) did not study SMEs separately and used only one indicator of digitalization - DESI, which can be considered a measure of digital transformation and assessed the impact of digitalization in general on GDP and the unemployment rate. With these input and output variables, Bulgaria, Cyprus, Hungary and Romania have made the most effective use of digitalization. According to Mehmet (2019), Bulgaria showed the highest input efficiency among all European countries, while it has the lowest input values in many categories. Germany, with high macroeconomic indicators, also showed very low digitalization efficiency.

CONCLUSIONS

The article proposes a method for forming a rating of European countries based on the economic effect of digitalization on the activities of enterprises of various sizes. For this purpose, DEA models were built to assess the efficiency of the digitalization used by small and medium-sized enterprises (number of employees from 10 to 250) and large companies (more than 250 employees). Input and output variables were selected to assess the impact of the level of digital transformation of SMEs and large companies in EU countries on their economic development. The use of the VRS model, in our opinion, is better suited for assessing the effectiveness of digitalization in EU countries. The fact is that EU countries differ significantly in size, economic development and degree of digitalization. The VRS model better accounts for these differences, allowing each country's performance to be analyzed based on its unique conditions and potential for growth, regardless of its economic size. Digitalization can have a non-linear impact on the country's economy. For example, smaller countries may be able to achieve high levels of digitalization with relatively low investment, while larger countries may require significantly greater investment to achieve similar digital transformations. The VRS model allows for these variable returns to scale to be taken into account. In addition, digitalization includes a wide range of indicators, from infrastructure to user skills, innovative digital services and digital citizen participation. The VRS model is better suited to analyze these various aspects because it can take into account the heterogeneity of input and output data.

Among SMEs, the leaders in digital intensity in 2022 were Denmark, the Netherlands, Sweden, Finland, Malta and Belgium, with the rate of enterprises with a high level of digital intensity approaching 40%. Of these, only Malta and the Netherlands showed maximum efficiency in the use of digitalization in the context of economic development, taking into account variable returns to scale based on the VRS model. The maximum efficiency in the VRS model among SMEs was demonstrated by countries with a high level of GDP per capita - Germany, Luxembourg and countries with the lowest level of GDP per capita - Romania and Bulgaria. Interestingly, SMEs in Finland, which is a leader in the adoption of digital technologies among this type of enterprise, were the least effective, indicating an insufficient return on investment in the digital transformation of SMEs.

Among large companies, the leader in digital transformation in 2022 was Denmark with a rate of enterprises with a high level of digital intensity of 52.3%, but the efficiency according to VRS models was only 66.77%, indicating that the return on digitalization of large companies in Denmark is not the benchmark among EU countries. The analysis showed that the effectiveness of digital transformation of small and medium-sized enterprises is somewhat inferior to the effectiveness of digitalization of large companies. This indicates that investments in the digitalization of large businesses bring greater returns to the national economies of EU countries compared to small and medium-sized businesses. The Scandinavian countries' poor performance can be explained by their leadership in digital adoption, but at the same time by their weaker economic performance, especially in exports and international investment.

The analysis showed that the efficiency of digitalization of SMEs and large companies based on the CRS model is almost the same, although large companies are significantly ahead of SMEs in the level of digitalization. In the case of VRS models, when accepting the assumption of variable returns to scale, which, in our opinion, more correctly models the task posed to the study, the average efficiency of large companies is higher than SMEs. Thus, we can conclude that the economic effect of the digital transformation of large businesses in the EU countries is higher compared to small and medium-sized businesses.

The obtained results based on the proposed DEA models enable regulators and national governments to determine the progress of SMEs in the process of digital transformation, monitor the achievement of goals and adjust plans according to the obtained results, determine where it is better to invest resources to achieve the maximum return from digitalization, ensuring the effective use of capital and resources. The results suggest that the expenses incurred from the digital transformation of large companies are more effectively recuperated than those of SMEs, particularly in terms of the impact of digitalization on the GDP, investment activities, and international trade within EU countries.

Prospects for further scientific research may consist of determining the effectiveness of the scale of digitization based on the VRS and CRS estimates obtained in the work. It is also an important task to establish causal relationships between performance indicators and the level of digitization of national economies.

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ADDITIONAL INFORMATION

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CONFLICT OF INTEREST

The Authors declare that there is no conflict of interest.

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АНАЛІЗ ЕФЕКТИВНОСТІ ЦИФРОВІЗАЦІЇ МАЛИХ ТА СЕРЕДНІХ ПІДПРИЄМСТВ КРАЇН ЄС ЗА ДОПОМОГОЮ DEA-МОДЕЛЕЙ

Процес цифровізації бізнесу передбачає постійні інвестиції та додаткові витрати, що призводить до неминучого дослідження економічних наслідків цифрової трансформації. Зокрема, важливо оцінити, як цей процес сприяє економічному зростанню країн. У статті представлено методику створення рейтингу європейських країн за економічними вигодами, отриманими від цифровізації бізнесу різного масштабу. Для досягнення цієї мети були розроблені моделі DEA, які вимірюють ефективність упровадження цифрових технологій малими та середніми підприємствами й великими корпораціями. Для вхідних змінних ми обрали показники, які відображають ступінь цифровізації бізнесу, зокрема частку МСП (малих та середніх підприємств) із високим індексом цифрової інтенсивності (DII), відсоток МСП, які використовують хмарні технології, та внесок обороту МСП у загальний оборот електронної комерції. Змінними обсягу виробництва були обрані показники, що свідчать про стан економіки країни: ВВП на душу населення, відношення експорту до ВВП та міжнародна інвестиційна позиція. Дані свідчать, що через значні відмінності в розмірах, економічному просуванні та рівнях цифровізації між країнами ЄС, модель VRS більш коректно враховує ці диспропорції. Цей підхід дозволяє оцінювати діяльність кожної країни на основі її унікального становища та потенціалу розвитку, без урахування її економічних масштабів. 2022 року Данія, Нідерланди, Швеція, Фінляндія, Мальта й Бельгія стали лідерами за цифровою інтенсивністю серед МСП, причому майже 40% компаній продемонстрували високий рівень цифрової взаємодії. Серед цих лідерів лише Мальта та Нідерланди досягли найвищої ефективності

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у використанні цифровізації для економічного зростання, що визначається моделлю VRS, яка враховує змінну віддачу від масштабу. Показано, що економічний ефект від цифрової трансформації для великих підприємств у країнах ЄС є більш суттєвим, ніж для малих і середніх підприємств.

Ключові слова: цифровізація, МСП, країни ЄС, індекс цифрової інтенсивності, модель DEA, VRS, CRS, економічне зростання, ефективність, продуктивність, ВВП на душу населення

JEL Класифікація: C67, L25, L11, F63