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DOES THE PRESENCE OF DIGITAL INNOVATIONS SERVE AS A CATALYST FOR ATTRACTING FOREIGN DIRECT INVESTMENT IN EUROPEAN UNION COUNTRIES?

Introduction

Digitalization has radically transformed the global economy and has become a driver of the Fourth Industrial Revolution. The 9th Sustainable Development Goal of the UN, «Industry, Innovation, and Infrastructure,» aims by 2030 to promote sustainable industrialization, expand scientific research, modernize technological capabilities of industrial sectors in all countries, encourage innovation, and significantly increase the number of researchers as well as public and private spending on research and development. Additionally, it seeks to significantly expand access to information and communication technologies and ensure Internet access [1].

Digital transformation is also one of the key priorities of the EU. At the beginning of 2024, the European Commission presented new initiatives for the development of digital infrastructure. The press release also stated that the future competitiveness of the EU economy will be based on advanced digital network infrastructures and services [2].

The UNCTAD report «World Investment Report 2017 – Investment and the Digital Economy» noted that the digital economy is changing

global investment processes [3]. Countries with developed digital infrastructure, as noted in our study [4], have significant advantages in attracting external capital, as they are more predictable in terms of business conduct, transaction transparency, and corruption risk reduction. Digital technologies are transforming foreign investment processes, creating innovative opportunities to enhance their efficiency. In 2023, at the annual meeting of the World Economic Forum in Davos, it was noted that «digital transformation is no longer a luxury, but a necessity for developing economies. To develop the digital economy, markets must attract and promote the increase of foreign direct investment (FDI) flows, which bring not only capital but also knowledge, technology, and know-how» [5].

Research on the impact of digital transformations on FDI processes has been actively conducted since the beginning of the 21st century. In one of the early studies, C. Choi (2003) found that the Internet, as the basis of any digital innovation (note by the authors), promotes FDI attraction through productivity growth; empirical regression results showed that a 10% increase in Internet users in a recipient country causes FDI volumes to grow by more than 2% [6]. E. R. Banalieva and S. Dhanarai (2019) found a negative impact of digitalization on the scale of international investment activities; in their work, they argue that digitalization reduces FDI volumes abroad, as digital innovations allow becoming a subject of international economic relations without real capital investments in other countries [7].

L. T. Ha and N. T. T. Huyen (2022) assessed the impact of digitalization on FDI in EU countries during the COVID-19 pandemic. In their study, they considered the impact of factors such as Internet use, business digitization, e-commerce, and digital public services on net FDI inflows, measured as a share of GDP in a given country in a given year, and found a nonlinear relationship between them. As a result, the researchers concluded that a certain degree of digital transformation can promote the attraction of foreign capital [8]. O. N. Zaevska, D. Pegoraro, and L. Piscitello (2024) provide evidence of the relationship between digitalization policies and FDI volumes. In particular, the volumes of state aid in the context of enterprise digitalization and the

presence of an Industry 4.0 ecosystem contribute to attractiveness for foreign investors. According to the Regional Innovation Scoreboard (RIS 2021), moderate or strong innovation regions in the EU have higher FDI volumes [9].

In recent years, the European Union has successfully implemented digital technologies in various spheres of social and economic life. The experience of this group can serve as a model for other countries and regions. The wide range of aspects covered by the EU allows analyzing different approaches and strategies to digital transformation in investment relations. Sustainability and resilience are key features of the EU's experience, as many of its countries have already made significant steps towards digitalization, allowing the study of the impact of these changes on the economy and society over a long period. The regulatory frameworks that the EU develops and implements to promote digitalization can become an important source of learning for other countries seeking effective methods of digital technology regulation. Studying the EU's experience can provide practical guidance on effectively addressing these challenges, promoting the development of sustainable and innovative strategies.

The aim of the study is to determine whether the digitalization of the economies of EU countries, assessed by the DESI index, has contributed to their attractiveness in terms of foreign investment. For a more detailed analysis, we divided the EU countries into three groups based on their level of digitalization according to the DESI index. The main task is to identify, within these groups, significant factors of the digital environment and their impact on internal investment flows.

Methodology

To achieve the objective, we utilized longitudinal (panel) data sets, which are a combination of cross-sectional and time-series data. Such information bases are used for the analysis, forecasting, and modeling of economic processes at both macro and local (regional) levels [10]. Since 2014, the European Commission has been monitoring the digital progress of EU countries using the Digital Economy and Society Index (DESI).

The DESI evaluates the level of digital technology development in a country based on five main sub-indices (Table 1).

Table 1

Characteristics of DESI Sub-Indices [11]

Sub-Index	Description	Significance
Connectivity	Evaluates the quality and availability of internet infrastructure, including broadband coverage and connection speed.	A high level of connectivity is critical for supporting digital services and innovation, making a country more attractive to investors seeking reliable and modern infrastructure.
Human Capital	Assesses the level of digital skills among the population and the availability of qualified ICT specialists.	A high level of human capital in the digital sphere is an important factor for investors, as it ensures the presence of personnel capable of supporting and developing digital technologies and innovations.
Use of Internet	Measures the degree of activity of the population in using the internet for various purposes, including online shopping, banking, social networks, and other services.	A high level of internet use among the population indicates the maturity of the digital market and the presence of consumers ready to engage with digital products and services, which is important for investors.
Integration of Digital Technology	Measures the degree of digital technology implementation in business, including the use of e-commerce, digital services, and technologies.	This sub-index shows how actively businesses are adopting and using digital innovations, which is an important indicator for investors looking for a favorable digital environment for their investments.
Digital Public Services	Evaluates the level of development and availability of digital public services, including e-government services for citizens and businesses.	This sub-index reflects the efficiency and convenience of government processes in a digital format, which can significantly increase investor confidence in a country by simplifying administrative procedures and improving the business environment.

To understand the overall progress in digital transformation and identify trends in the development of digital technologies, it is important to analyze the dynamics of the average DESI index for the 27 EU countries over the period 2017–2022 (Fig. 1).

From Fig. 1, we observe that during the period 2017-2019, the average DESI values gradually increased, indicating the continuous adoption of digital technologies and policies across EU countries. However,

with the onset of the pandemic in 2020, there was a rapid acceleration of digitalization driven by the necessity to adapt to new conditions such as remote work, online education, telemedicine, and other digital services. Additionally, in 2021, the EU launched the «Digital Compass,» which defines digital transformation goals up to 2030. This initiative likely further stimulated EU countries towards accelerated adoption of digital technologies and policies, reflected in high DESI values in 2021–2022. Thus, the dynamics of DESI for the period 2017–2022 demonstrate significant growth in digital maturity among EU countries, particularly in response to the challenges posed by the COVID-19 pandemic and under the influence of new European initiatives aimed at supporting digital transformation.

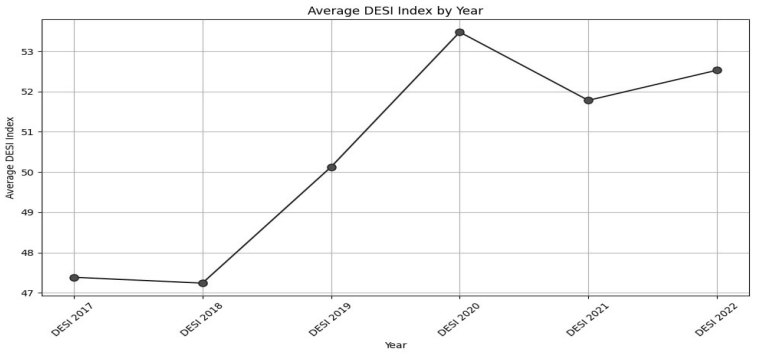
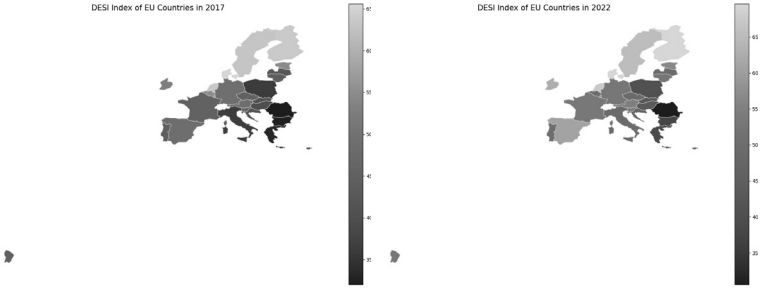


Fig. 1. Dynamics of the average DESI index for the 27 EU countries

To better understand the impact of various factors on digital transformation in EU countries and to identify changes in trends and intensity of digital technology adoption, we divided the study period into two sub-periods: 2017–2019 – EU countries implemented digital technologies according to national and pan-European strategies (infrastructure development, improvement of digital skills among the population, increased use of digital services, etc.); 2020–2022 – the pandemic and EU initiatives accelerated the adoption of digital solutions across many countries and businesses (increased demand for remote work, online education, the Digital Compass program, etc.).

While the average DESI score increased, significant differences exist between countries within the EU in terms of digital maturity, reflected in their DESI scores. Some countries demonstrate faster growth than others, depending on their initial conditions and investments in digital infrastructure. These differences are confirmed by interactive maps of the EU based on the DESI index at the beginning and end of the study period (Fig. 2).



а) *б)*

Fig. 2. Interactive maps of the EU based on the DESI index: a) 2017; b) 2022

Fig. 2 allows for a visual assessment of changes occurring in each country over the study period. This serves as a basis for a deeper analysis of the dynamics of the average DESI index across the 27 EU countries. Additionally, Fig. 2 enables the identification of countries that have made the most progress in their DESI indicators and those with slower growth rates, analyzing potential reasons for these outcomes, which may include economic, social, or political factors. It is also evident that the geographic location of countries can influence their DESI index scores due to various factors such as infrastructure availability, cultural characteristics, and others. Specifically, Eastern and partially Southern European countries exhibit similar levels of digital technology development due to comparable economic conditions or infrastructural opportunities, resulting in lower DESI scores. Central and Western European countries show slightly higher values in the investigated indicator, indicating more extensive digital infrastructure or high adaptability to advanced technologies. Northern European countries are

characterized by the highest DESI values due to high accessibility and utilization of digital technologies in everyday life.

Thus, for a better understanding of how different EU countries are progressing digitally and to identify areas requiring additional efforts in research, cluster analysis was conducted based on the DESI index for each of the two periods. In the initial stage of cluster analysis, the «elbow» method was employed to determine the optimal number of clusters. This method relies on plotting the sum of squared distances within clusters (WCSS) against different numbers of clusters. The goal is to identify the «elbow point» on the graph (Fig. 3), where further increasing the number of clusters results in only a slight decrease in WCSS. This point indicates the optimal number of clusters.

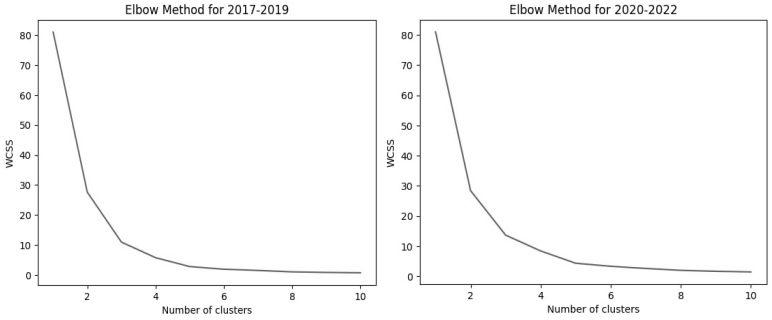


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Fig. 3. Elbow method for determining the number of clusters based on the DESI index: a) 2017–2019; b) 2020–2022

From Fig. 3, we determine that the optimal number of clusters for both periods is 3. The next step involved clustering using the k-means method, which partitions the data into clusters by minimizing the within-cluster sum of squares. Thus, for each studied period, all EU member states were classified into three clusters based on the intensity of digital technology adoption, specifically: high, medium, and low DESI values.

To visualize the results of the cluster analysis, Principal Component Analysis (PCA) was applied. PCA reduces the dimensionality of multidimensional data to two components for ease of visualization.

PCA retains maximum variation in the data, allowing for a clear representation of data structure and interactions between different clusters (Fig. 4).

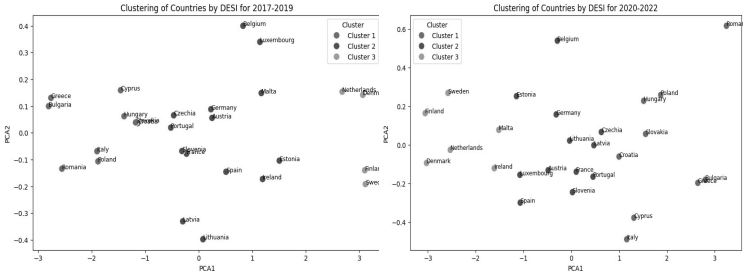

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Fig. 4. Visualization of clusters in the two-dimensional principal component space: a) 2017–2019; b) 2020–2022

The results of cluster analyses for the periods 2017–2019 and 2020–2022 are presented in Table 2.

Table 2

Results of Cluster Analyses for the Periods 2017–2019 and 2020–2022

2017–2019	2020–2022
Cluster 1 Bulgaria, Greece, Croatia, Italy, Cyprus, Hungary, Poland, Romania, Slovakia	**Cluster 1** Bulgaria, Greece, Croatia, Italy, Cyprus, Hungary, Poland, Romania, Slovakia
Cluster 2 Belgium, Czech Republic, Germany, Estonia, Ireland, Spain, France, Latvia, Lithuania, Luxembourg, Malta, Austria, Portugal, Slovenia	**Cluster 2** Belgium, Czech Republic, Germany, Estonia, Spain, France, Latvia, Lithuania, Luxembourg, Austria, Portugal, Slovenia
Cluster 3 Denmark, Netherlands, Finland, Sweden	**Cluster 3** Denmark, Ireland, Malta, Netherlands, Finland, Sweden

Countries in Cluster 1 are characterized by relatively low DESI scores, indicating an initial level of digital maturity. Throughout both periods, these countries remain in Cluster 1, reflecting slow progress

in digitalization. This may indicate insufficient investments in digital infrastructure, education, and skills, necessitating significant support to improve their digital economy.

Countries with moderate DESI scores, showing potential for growth and development, fall into Cluster 2. These countries have demonstrated stable development by investing in digital infrastructure and services. Most of them retained their positions in this cluster, although Ireland and Malta moved up to Cluster 3 in 2020–2022.

Countries with high DESI scores, leading in the digital economy, belong to Cluster 3. They continue to demonstrate high levels of innovation and investment in the digital sector, enabling them to maintain their leadership position.

Thus, based on the results of cluster analysis, most countries maintain their positions in the respective clusters over both periods, indicating stable development of their digital maturity. The COVID-19 pandemic accelerated digitalization, particularly noticeable in countries that moved to higher clusters in the second period (such as Ireland and Malta). Additionally, cluster analysis underscores significant differences in the level of digital maturity among EU countries. Leaders continue to strengthen their positions, while countries with low DESI scores require greater support to enhance their digital infrastructure. Countries in Cluster 1 need substantial investments in digital infrastructure and skills development to catch up with moderate and high DESI scores.

Results and Discussion

After clustering countries based on the intensity of digital technology adoption, a multiple regression analysis was conducted to examine the impact of digital innovations on inward foreign direct investment (FDI) for each cluster in two periods: 2017–2019 and 2020–2022. The adequacy of all constructed regression models is confirmed by residual analysis.

The selection of independent variables for analysis was based on key aspects defining the country's level of digital transformation included in the DESI index.

The dependent variable chosen was Inward FDI. The factorial features for the multiple regression analysis concerning the 5 DESI sub-indices are presented in Table 3.

Table 3

Description of factorial features related to their inclusion in DESI sub-indices

Sub-index	Factorial Variables	Description
Connectivity	Broadband internet coverage by speed (More than 100 megabits per second (Mbps) (Percentage of households))	The spread of high-speed internet is crucial for digital infrastructure that supports all other digital services and applications.
	Level of internet access (Percentage of households) – households	The level of household internet access demonstrates basic digital infrastructure, which is fundamental for the development of other digital services.
Human Capital	Employed ICT specialists (Percentage of total employment)	The number of ICT specialists indicates the availability of skilled workforce to support and develop digital technologies, which is a critical factor for investors.
Use of Internet Services	Internet purchases by individuals	The number of internet purchases reflects the population's activity and readiness for digital commerce, influencing market attractiveness for investors.
	Individuals – internet use (Percentage of individuals who used Internet within the last year)	The overall internet usage rate among the population shows how integrated digital technologies are in citizens' daily lives.
	Promoting e-commerce for individuals	Encouragement of e-commerce among the population demonstrates how actively citizens use digital platforms for shopping, contributing to the development of the digital economy.
Integration of Digital Technology	e-banking	The development of electronic banking indicates a high level of trust and usage of digital financial services, which can attract investors valuing a country's digital readiness.
	Selling goods or services	The sale of goods and services online demonstrates the degree of integration of e-commerce into the economy, which is an important factor for companies planning to invest in the country.
	Promoting e-commerce for business	Support for e-commerce among businesses indicates support for enterprise digitalization, which is an attractive factor for foreign investors.
Digital Public Services	E-government activities of individuals via websites	The use of electronic government services reflects the level of digitalization in government processes and convenience for citizens, which can attract investors.

Thus, all indicators are categorized according to DESI sub-indices, demonstrating their importance in assessing the level of digital readiness of countries and their ability to attract FDI.

The results of the multifactorial regression analysis for the first cluster during the period 2017–2019 show, that digital innovations have a significant impact on attracting FDI (Fig. 5).

Regression results for Cluster 1:
Regression results for Inward FDI:

OLS Regression Results

Dep. Variable:	Inward FDI	R-squared:	0.643
Model:	OLS	Adj. R-squared:	0.575
Method:	Least Squares	F-statistic:	9.384
Date:	Thu, 20 Jun 2024	Prob (F-statistic):	1.16e-08
Time:	02:23:43	Log-Likelihood:	-454.82
No. Observations:	63	AIC:	931.6
Df Residuals:	52	BIC:	955.2
Df Model:	10		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	2042.7434	896.724	2.278	0.027	243.335	3842.152
e-banking	18.3853	12.844	1.431	0.158	-7.389	44.160
Selling goods or services	-42.3645	10.207	-4.151	0.000	-62.846	-21.883
Promoting e-commerce for individuals	-54.3433	24.039	-2.261	0.028	-102.581	-6.105
Promoting e-commerce for business	14.5753	9.590	1.520	0.135	-4.668	33.818
Internet purchases by individuals	31.4447	29.070	1.082	0.284	-26.888	89.778
Broadband internet coverage by speed	11.7360	3.292	3.565	0.001	5.131	18.341
Individuals - internet use	-145.6024	41.506	-3.508	0.001	-228.891	-62.314
Level of internet access - households	-18.0922	10.922	-1.656	0.104	-40.010	3.825
E-government activities of individuals via websites	-1.4855	7.332	-0.203	0.840	-16.198	13.227
Employed ICT specialists	17.3949	148.715	0.117	0.907	-281.024	315.814

Omnibus:	1.641	Durbin-Watson:	2.199
Prob(Omnibus):	0.440	Jarque-Bera (JB):	1.495
Skew:	0.369	Prob(JB):	0.474
Kurtosis:	2.840	Cond. No.	2.19e+03

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

Fig. 5. Results of regression analysis for Cluster 1, Period 2017–2019

For the period 2017–2019, countries in Cluster 1 show a model with a high coefficient of determination (0.643), indicating that 64.3% of the variation in inward FDI can be explained by the included independent variables. However, some variables were found to be statistically significant while others were not. Specifically, variables such as «Selling goods or services», «Promoting e-commerce for individuals», «Broadband internet coverage by speed», and «Individuals – internet use» have statistically significant impacts on the level of inward FDI (p-value < 0.05). Additionally, coefficients for «Selling goods or services» and «Promoting e-commerce for individuals» are negative, suggesting that an increase in these indicators is associated with a decrease in FDI. This could be explained by increased competition in the domestic market due to e-commerce development and increased sales, potentially reducing the country's attractiveness for foreign investments, particularly in retail trade. Conversely, positive coefficients for variables like «Broadband internet coverage by speed» and «Individuals – internet use» confirm that fast and accessible internet enhances business process efficiency and attracts new technologies, stimulating increased FDI. Higher levels of internet usage

among the population also indicate high digital readiness, making the country more attractive to investors who value the availability of digital tools and platforms. These economic impact changes demonstrate how the development of digital technologies can have varying consequences for a country's economic activity. Negative impacts may reflect competitive challenges or unfavorable business conditions, whereas positive impacts underscore the role of digital infrastructure in stimulating economic growth and attracting foreign investments.

For the period 2020–2022, the same countries in Cluster 1 experienced increased influence of digital innovations on attracting foreign direct investment (FDI) compared to the previous period. A coefficient of determination of 0.759 indicates that 75.9% of the variation in inward FDI can be explained by the included independent variables. This significant increase from 64.3% for the period 2017–2019 demonstrates improved explanatory power of the model. Variables such as «Selling goods or services», «Promoting e-commerce for individuals», and «Internet purchases by individuals» continue to have statistically significant impacts on the level of inward FDI. Based on the coefficients associated with these variables, we conclude that active promotion of e-commerce for individual consumers reduces the country's attractiveness for foreign investments, and increased internet purchases among the population negatively affects external economic indicators such as foreign investments, potentially due to reduced demand for traditional markets. These results underscore the importance of a balanced approach to digital innovation development, considering not only positive but also potential negative economic consequences. Similar multifactor regression analyses were conducted for Clusters 2 and 3 across the periods.

Specifically, for countries in Cluster 2 during the period 2017–2019, multifactor regression analysis results show significant influence of digital innovations on attracting foreign direct investments (FDI). The coefficient of determination suggests that 96.6% of the variation in inward FDI can be explained by the included independent variables. For the period 2020–2022, countries in Cluster 2 showed even stronger impact of digital innovations on FDI. With a coefficient of determination close to 1.000, almost all variation in inward FDI is explained by the included variables. Key findings for both periods indicate that significant variables

influencing the level of inward FDI include «Promoting e-commerce for business» and «Level of internet access – households».

Additionally, the negative coefficient for the variable «Promoting e-commerce for business» may indicate that a focus on developing e-commerce for businesses could impact the competitiveness of traditional industries or create undesirable risks for investors. In contrast, the positive coefficient in the regression model for the variable «Level of internet access – households» shows a positive effect on FDI. This may reflect that a high level of internet access in households contributes to creating a favorable environment for businesses and stimulates innovation, which, in turn, attracts foreign investment.

The results of the analysis for countries in Cluster 3 during the period 2017–2019 (R2=0.784) identified the following significant factors: «e-banking,» «Selling goods or services,» «Promoting e-commerce for individuals,» «Promoting e-commerce for business,» «E-government activities of individuals via websites,» and «Employed ICT specialists.» Some of these factors have negative coefficients. For countries with the most developed digital technologies, increased use of internet banking is associated with a decrease in incoming foreign direct investment (FDI); higher volumes of goods or services sales may also reduce the attractiveness of the country for foreign investment; initiatives supporting e-commerce for businesses have a negative impact on FDI; and active participation of individuals in government activities via websites also diminishes the country›s attractiveness for external investment. Conversely, active promotion of e-commerce among individual consumers contributes to an increase in FDI, and an increase in the number of employees in the information and communication technology sector positively impacts FDI by enhancing the country›s technological readiness and innovation potential.

Thus, the results of the study demonstrate the importance of analyzing individual factors of digital innovations for economic development and attracting foreign investments, as well as the need for a balanced approach to their regulation and support.

For the period 2020–2022, the countries in Cluster 3, which expanded due to significant advancements in digital transformations by Ireland and Malta after the pandemic, show the following key results

from the multifactorial regression analysis (R2=0.746): «Promoting e-commerce for business,» «Individuals – internet use,» and «Employed ICT specialists.» The first two variables have negative coefficients, indicating that measures supporting e-commerce for businesses have a negative impact on the level of incoming foreign direct investments (FDI). This may be related to risks for local companies or other economic factors. Additionally, increased internet usage among the population leads to a reduction in incoming FDI, which could be associated with low digital literacy among part of the population or other socio-economic aspects. Nonetheless, an increase in the number of employees in the information and communication technology sector positively impacts the level of FDI.

These results highlight the complexity of the impact of digital innovations on the country›s investment climate and the necessity of careful analysis of specific factors and the context of their impact on the economy.

Conclusions

The research results demonstrate the existence of complex interdependencies between the development of digital innovations in EU countries and their investment attractiveness. They also highlight the importance of a more detailed study of the impact of specific components of the digitalization process on the economy and the need for a balanced approach to their regulation and support. The digitalization process in the European context, considering significant economic and sociocultural differences between countries, is uneven. This is confirmed by the results of clustering countries by the DESI index. In recent years, the most effective implementation of digital innovations has been in the countries of Northern Europe and Malta, with the second cluster formed by the Baltic, Central, and Western European countries, while the least digitalized remain the countries of Southeastern Europe.

It is unequivocal that digitalization impacts the volumes of foreign direct investment (FDI) attracted; however, due to the complexity and multifaceted nature of this process, different combinations of factors are observed in each case. The impact of digital innovations was most pronounced during and after the COVID-19 pandemic when EU leaders

recognized their necessity and importance. This is confirmed by the declaration of the Digital Compass: the European way for the Digital Decade, which was presented at the beginning of 2021. The internet, as the foundation of digital innovations, contributes to increasing technological readiness and innovation potential, which positively affects the investment attractiveness of countries. Empirically, a negative correlation between the volumes of foreign direct investment and e-commerce has been confirmed across all EU member states. This is explained by the fact that e-commerce reduces the volumes of traditional imports and exports on which external investors rely. A similar effect is observed in studies of the interrelationship of these processes in China [12] and African countries [13].

This research expands the understanding of the impact of digital transformations in EU countries on various socio-economic processes, particularly their international investment activities. The DESI index indeed allows for assessing progress in the field of digitalization; however, there are certain limitations associated with the short period of available data and changes in the calculation methodology. Studying the experience of advanced countries in attracting foreign investments through the lens of digitalization is crucial for Ukraine, which is currently rapidly implementing digital innovations amid its full-scale war with Russia.

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