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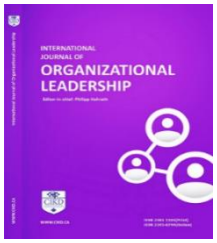

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Effectiveness of Digital Integration in the Economy and Society Amid Ongoing Economic Transformation

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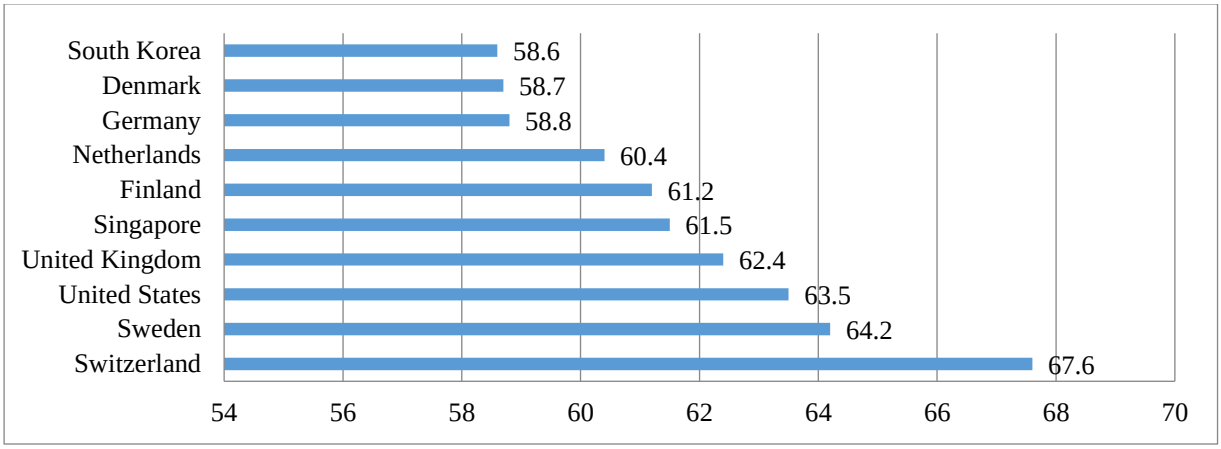
ABSTRACT

Researching the effectiveness of digital adaptation of the economy and society at the current stage of economic transformation is relevant because countries seeking to strengthen their positions in the global economy are increasingly interested in effective mechanisms of digital adaptation aimed at increasing productivity and innovation and achieving long-term sustainable development of society. The main aim of this research article is to study the effectiveness of the digital adaptation of the economy and society at the current stage of economic transformation. The study used several general scientific methods of cognition, including synthesis of literature sources, comparative analysis, methods of systematisation and generalisation, and statistical data analysis, to form the initial data of regression analysis, which identified the relationships between dependent and independent variables and forecast trends in the growth of Ukraine's digital adaptability. According to the results of the regression analysis, the model that takes into account social indicators (M0) has a high level of correlation but needs to improve the forecast accuracy. The model that considers economic indicators (M1) has the highest correlation and explanatory power and demonstrates high forecast accuracy. The model that views all possible variables (M2) has benchmark values of correlation and explanatory power, but the inclusion of additional indicators can reduce the forecast accuracy in general. The level of digital adaptability will significantly impact Ukraine's economic and social stability in the future. However, facing current challenges requires strengthening infrastructure and institutional capacity and focusing on integrating digital technologies into all spheres of life.

Today, digital technologies play a crucial role in shaping the modern global economic environment, determining the direction of development of economic and social systems in countries around the world. Given the high level of technological achievements and the readiness of many developed countries for digital transformation, it is important to note that some countries demonstrate the highest level of innovation, providing investments in the development of digital technologies and supporting start-ups in the fields of technology, robotics, artificial intelligence and other new areas. As shown in Figure 1, the most innovative countries in the world are actively developing institutional and infrastructure support and creating a favourable environment for the development of science, business and society.

Figure 1

The World's Most Innovative Countries According to the Global Innovation Index in 2023



Source: Dyvik (2024)

The current stage of economic transformation is characterised by digital intensification, which involves introducing innovative technologies, expanding information infrastructure, and integrating digital solutions into all areas of economic activity. This stage is accompanied by significant technological, environmental and social changes, which require adapting management models, norms and development strategies. In such circumstances, the national economies of developed countries are actively transitioning to new technological modes, focusing on innovation, technology, creativity and digital sectors as key factors in ensuring sustainable development. Thus, the effectiveness of digital adaptation of the economy and society is becoming an important factor in increasing the competitiveness of countries, which determines the priority of developing and implementing digital technologies in various areas of economic activity.

This research article aims to study the effectiveness of digital adaptation in the economy and society at the current stage of economic transformation. It includes a theoretical justification of the state and problems of digital adaptation and an analysis of further trends towards increasing the economy and society's adaptability to digital intensification.

Literature Review

The modern era is characterised by accelerating processes of innovative renewal covering all aspects of socio-economic life, so economic transformation remains a key element of the social and economic development of countries in the global environment. McMillan et al. (2017) and

Vahonova et al. (2022) define economic transformation as a dynamic process that includes structural changes by redistributing labour and resources from low to high-productivity sectors and optimising economic growth by prioritising strategic industries based on innovative technologies. Instead, Weldegiorgis et al. (2022) consider it a structural variable caused by the reallocation of resources, which leads to productivity growth, economic diversification and industrialisation. In this context, Lin (2017), Ing and Lin (2024), and Yudhoyono et al. (2024) pay special attention to the importance of a country's factor resources (e.g., natural resources, labour force, human and physical capital), which are the totality of available resources for distribution among the primary, secondary and tertiary sectors to create goods and services. The most clear-cut distinction between stages of economic growth was proposed by Rostow (1990) in his work entitled "Rostovian take-off model of economic growth". As interpreted by Geyer and Pickering (2011), Rostow's economic growth model emphasises a linear progression towards a pre-determined endpoint of economic maturity, guided by external expertise and policy prescriptions. According to Gaur et al. (2023), in this framework, local actors (i.e., governments, businesses, NGOs, and the population of a developing country) passively follow strategies designed by Western experts who prioritise rapid progress along the path, minimising local input or experimentation. The current stage of economic transformation can be defined as digital intensification, where the key role is played by introducing innovative technologies, expanding information infrastructure and integrating digital solutions into all areas of economic activity (Litvinenko, 2020). The digital adaptation of society is determined by the level of access to digital technologies, the development of digital skills, and the introduction of inclusive technologies in various social spheres (Colomo-Magaña et al., 2024; Johnson et al., 2024; Peláez et al., 2022). According to the WSIS Forum in 2021, digital technologies improve the quality of education, healthcare, and social services (Ronchi, 2021). At the same time, the digital divide between different social groups is growing, which can increase inequality and social exclusion (Li & Kostka, 2024). The literature emphasises that digital technologies play a crucial role in overcoming both global crises, such as the COVID-19 pandemic, and local challenges, such as Russia's ongoing aggression in Ukraine, by facilitating the transition to new models of remote work and e-governance (Bilan et al., 2023; Maikomo et al., 2021). For example, in Ukraine, the digitalisation of the public sector through initiatives such as Diia shows significant potential to increase transparency and governance efficiency (Oliychenko et al., 2024; Yeretin et al., 2024). Thus, the digital adaptation of the economy and society is a multifaceted process encompassing structural, economic and social aspects. The effectiveness of this process depends on the ability of the state and society to integrate digital technologies into all spheres of human life, minimising the risks associated with the digital divide and automation. In the context of economic transformations, digitalisation acts as a catalyst for innovative development, helping to strengthen the competitiveness and sustainability of the economy in the context of globalisation.

Method

Qualitative Analysis

The following methods were used in the research:

- The synthesis of literature sources was used to identify the key problems of digital adaptation of the economy and society at the current stage of economic transformation;

- Comparative analysis was applied to compare the levels of innovation in the most developed countries of the world to assess their digital adaptability in the context of economic transformations;
- The method of generalisation was used to analyse the dynamics of changes in the Global Innovation Index indicators in Ukraine;
- The systematisation method was utilised to identify and analyse trends in the indicators characterising the level of digitalisation in Ukraine.

Quantitative Analysis

Based on the results of the statistical data analysis, the study describes the state of Ukraine's digital adaptation at the current stage of economic transformation, namely in the context of digital intensification, which includes the expansion of information infrastructure, integration of digital solutions and the growing role of digital technologies in all aspects of economic and social life. The data covers the period from 2014 to 2024, which allows us to assess the dynamics of changes in the indicators and provide an adequate assessment of Ukraine's digital adaptation processes at the current stage of economic transformation. The analysis methodology is based on the use of regression analysis to identify relationships between dependent and independent variables and forecast trends in the growth of Ukraine's digital adaptability.

1. This analysis's dependent variable (Y) is the value of the Global Innovation Index (GII Score), which reflects a country's overall level of innovation development and its ability to implement the latest technologies. The data source is the official reporting of the World Intellectual Property Organisation (WIPO). The data analysis of the dependent variable of the regression analysis is presented in Table 1.

Table 1

Analysing the Data of the Dependent Variable of Regression Analysis

Period	GII rank	Score	Income group rank (EUR)	Region rank
2014	63	36.26	3	36
2015	64	36.45	4	32
2016	56	35.72	2	34
2017	50	37.62	2	33
2018	43	38.52	1	30
2019	47	37.4	2	32
2020	45	36.32	2	30
2021	49	35.6	3	32
2022	57	31.0	4	34
2023	55	32.8	3	34
2024	60	29.5	4	34

Source: Dutta et al. (2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024)

2. Independent changes (X) were selected by researching UN reports to find relevant indicators that characterise the level of digitalisation. Based on the data processing results, the quantitative characteristics of Ukraine's progress in implementing digital technologies are the e-Government Development Index (EGDI), the e-Participation Index (EPART), the Telecommunications Infrastructure Index (TII), and the Online Services Index (OSI). The analysis of the independent variables of the regression analysis is presented in Table 2.

Table 2

Analysing the Data of Independent Variables in Regression Analysis

Period	Economic			Social	
	Online Services Index (OSI)	Telecommunications Infrastructure Index (TII)	e-Government Development Index (EGDI)	Human Capital Index (HCI)	e-Participation index (EPART)
2014	.26	.38	.50	.86	.43
2016	.58	.39	.60	.83	.74
2018	.56	.43	.61	.84	.68
2020	.68	.59	.71	.85	.80
2022	.81	.72	.80	.86	.60
2024	.98	.84	.88	.82	1

Source: United Nations (2024)

The choice of the above variables allows for a comprehensive analysis, considering the economic and social aspects of digital transformation. These indicators are also important for studying the relationship between innovation and developing digital infrastructure and society, which are critical for complete digital adaptation. The study developed regression models to assess the impact of social, economic and complex factors on the level of digital adaptability, namely

Model M_0: using only social independent variables;

M_1 model: using only economic independent variables;

M_2 model: inclusion of all possible variables in the model to assess their impact on the country's digital adaptability.

The initial data were imported into the JASP statistical software to obtain the regression analysis results and build a model for predicting Ukraine's further digital adaptation.

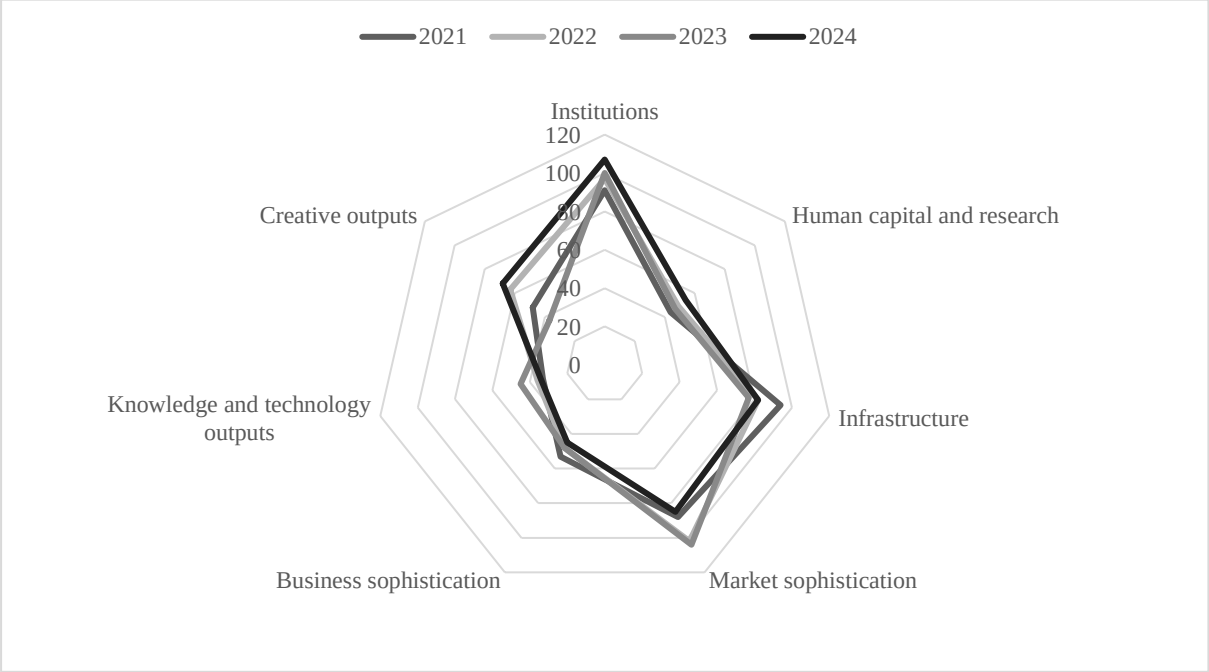
Results

Modern economic transformations are determined by the accelerated introduction of innovations that affect socio-economic processes, including the redistribution of resources between industries with different productivity levels and the development of strategic sectors based on scientific and technological innovations. Structural changes in the economy caused by such transformations contribute to productivity growth, diversification and industrialisation while being based on the efficient use of resources available to the primary, secondary and tertiary sectors.

In the current scientific literature, the current stage of economic transformation is characterised primarily by digital intensification, which includes the expansion of information infrastructure, integration of digital solutions, and the growing role of digital technologies in all aspects of economic and social life. The development of digital skills determines digital adaptation, access to innovative technologies, and the creation of conditions for the inclusive use of digital tools in various sectors. Therefore, digital adaptation is becoming a tool for overcoming crises and an element of an innovative development strategy in economic transformation. This process's key indicators indicate the level of innovation and digitalisation, which reflect the level of technological integration and readiness for innovative development. In particular, the values of the Global Innovation Index and its components, shown in Figure 2, allow for assessing countries' progress in creating favourable conditions for technological breakthroughs, efficiency of innovation activities and introduction of the latest technologies.

Figure 2

Dynamics of Changes in the Components of the Global Innovation Index in Ukraine



Source: Dutta et al. (2021, 2022, 2023, 2024)

Ukraine's digital adaptation, despite the large-scale challenges caused by Russia's war against our country, demonstrates resilience and some progress in key areas of innovative development. The war has had a significant impact on infrastructure, market, and business performance, but at the same time, it has stimulated rapid transformation in the digital sphere, which has become a key tool for ensuring economic viability. An analysis of the dynamics of the components of the global innovation index shows that some aspects of innovation development have deteriorated significantly. In particular, this applies to the institutional component, which decreased from 91 points in 2021 to 107 points in 2024 during the analysed period, indicating increased challenges in the legal and institutional environment. Similar dynamics are also observed in infrastructure support (down to 82 points in 2024), indicating more difficult access to modern technological solutions. At the same time, the continued stability of business capability indicators (the Business sophistication indicator increased to 45 points in 2024) demonstrates the need to support entrepreneurship and the technology sector.

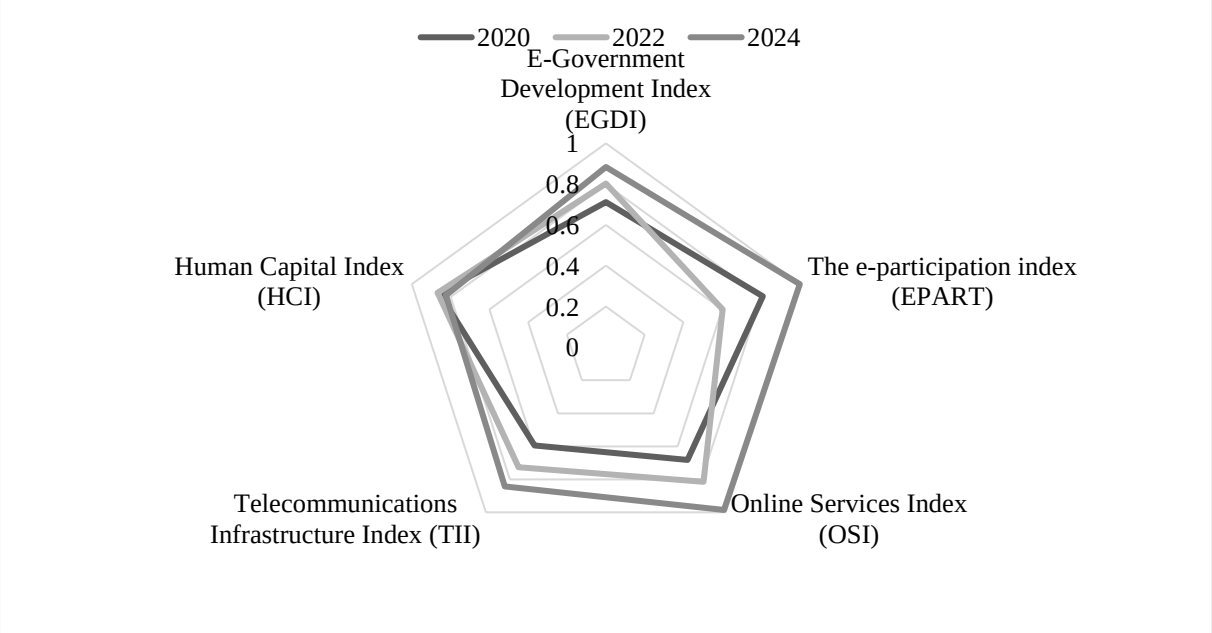
An important strategic vector for Ukraine is the digital economy's development, whose GDP share could reach 65% by 2030 under an accelerated scenario (Amelin et al., 2019). This scenario involves a radical restructuring of the economic system and the integration of digital technologies into all sectors of the economy, including industry and agriculture. Thus, integrating digital technologies into all sectors of the economy can compensate for a significant part of the losses caused by the war and create preconditions for economic recovery. Otherwise, the inertial scenario will leave Ukraine facing economic stagnation, continued human capital flight, and loss of competitiveness in global markets.

Along with the Global Innovation Index, indicators characterising the state of digital transformation, including the level of digital skills among the population, the level of access to information and communication technologies, and the integration of digital services into public

administration and business, are important for understanding Ukraine's digital adaptability, as shown in Figure 3.

Figure 3

Indicators Characterising the Level of Digitalisation In Ukraine



Source: United Nations (2024)

Given the growth of key indicators, including the EGDI by 24.18% and EPART to 1.0 in 2024, it can be concluded that Ukraine's digital adaptation has made significant progress over the analysed period, especially in the development of e-government, online services, and telecommunications infrastructure. However, the decline in the Human Capital Index (HCI) to .82 indicates the need to strengthen digital education and training for the sustainable development of the digital economy. These trends make it possible to state the most pressing problems of digital adaptation of the economy and society at the current stage of economic transformation (Table 3), as they demonstrate the degree of implementation of digital solutions and the country's readiness for the challenges associated with digital transformation, contributing to the analysis of the effectiveness of public policy in the field of digitalisation.

Table 3

Problems of Digital Adaptation of the Economy and Society at the Current Stage of Economic Transformation

Direction	Problem	Characteristics
Economic challenges	High cost of digital technology	Integration of modern technologies requires significant financial outlays, which becomes a barrier for small businesses and households.
	Poor support for SMEs	Limited access to favourable lending conditions or grants for implementing digital tools in small and medium-sized businesses hinders their development.
	Insufficient level of cybersecurity	Economic losses due to cyberattacks and weak data protection for businesses and citizens threaten trust in digital services.
Ecosystem issues	Weak state policy to stimulate innovation	Insufficient incentives, such as tax breaks or grants, for developing an innovative economy reduce the competitiveness of domestic enterprises on the global market.
	Immature investment capital market	Effective mechanisms for attracting investment are needed. Developing the venture capital market and business accelerators will boost start-up ecosystems.
	Outdated education system	The gap between actual training and labour market needs requires improving the quality of STEM disciplines and soft and entrepreneurial skills among the population.

Direction	Problem	Characteristics
	Low integration between science and business	Scientific research does not often find practical application in the economy due to the lack of effective models of technology transfer and cooperation between universities and businesses.
Infrastructure challenges	Low level of digital infrastructure development	Broadband Internet access covers only about 60% of Ukraine's territory, while the EU aims to cover 100% of its territory with broadband by 2020. This limits opportunities for businesses and society to digitalise.
	Limited infrastructure support	Underdeveloped infrastructure, particularly the Internet of Things, electronic identification, and trust, hinders the integration of modern technologies into industry, the public sector, and society.
	Unequal access to digital technologies	Digital divides between cities, villages, regions, and social groups are increasing social inequality and hampering the development of digital literacy and access to modern services.
Institutional challenges	Low involvement of state institutions	Public authorities' lack of systematic involvement in implementing the Digital Economy and Society Development concept leads to the absence of a comprehensive approach to digital transformation at the national level.
	Inconsistency of government strategies and programmes	Current national, regional, and sectoral programmes often do not take into account the real potential of digital technologies, which leads to inefficient resource use and slows innovation development.
	Fragmentation of efforts	The absence of a single state coordinator or body responsible for digitalisation leads to duplication of functions, inefficient use of budget funds and dispersion of efforts between institutions.
	Bureaucratic barriers	The excessive number of regulatory procedures makes launching and implementing digital projects difficult, particularly in e-government, which demotivates investors and entrepreneurs.
Social issues	Digital inequality	A significant proportion of the population lacks basic digital skills, which limits their access to information and economic opportunities.
	Cultural barriers	The population's distrust of digital services is caused by their fear of new technologies and the lack of a quality information campaign on their benefits.
	Risks of digital isolation	Due to a lack of support and training, the elderly, rural residents, and other vulnerable groups are excluded from the digitalisation process.
Challenges in e-governance	Low level of service automation	Government agencies are not sufficiently motivated to fully digitalise their processes because they do not understand the potential benefits of automation.
	Lack of a data management culture	Insufficient integration of open data principles into public administration limits the transparency and efficiency of public authorities.
	Privacy risks	The lack of effective mechanisms for protecting personal data in public and private digital services leads to public distrust and risks of privacy violations.

Source: Colomo-Magaña et al. (2024), Hansen-Addy et al. (2024), Ing & Lin (2024), Johnson et al. (2024), Krulevskiy (2024), Lin (2017), Litvinenko (2020), Oliychenko et al. (2024), Peláez et al. (2022), Yudhoyono et al. (2024).

The effectiveness of a country's digital adaptation in economic transformations is multifaceted and should include both social and economic components. Therefore, to analyse the development of socio-economic indicators of digital adaptation, it is important to justify the choice of source data, as the correct choice of variables allows for reliable and interpretable results. For the analysis, the global innovation index was chosen as the dependent variable and the key indicators of Ukraine's digital transformation as the independent variables. The independent variables were conditionally divided into two groups describing digital adaptation's social and economic aspects. The source data for the analysis of the development of socio-economic indicators of digital adaptation is presented in Table 4.

Table 4

Baseline Data for Analysing the Development of Socio-economic Indicators of Digital Adaptation

Period	Dependent variable	Independent variables				
		Economic			Social	
	Global Innovation Index (GII)	Online Services Index (OSI)	Telecommunications Infrastructure Index (TII)	e-Government Development Index (EGDI)	Human Capital Index (HCI)	e-Participation index (EPART)
2014	36.26	.26	.38	.50	.86	.43
2016	35.72	.58	.39	.60	.83	.74
2018	38.52	.56	.43	.61	.84	.68
2020	36.32	.68	.59	.71	.85	.80
2022	31.0	.81	.72	.80	.86	.60
2024	29.5	.98	.84	.88	.82	1

Source: compiled by the author based on Dutta et al. (2014), Dutta et al. (2016), Dutta et al. (2018), Dutta et al. (2020), Dutta et al. (2022), Dutta et al. (2024), United Nations (2024)

The dependent variable of the analysis is an important indicator of the development of innovation activity in the country, which is the basis for assessing digital adaptation, which allows us to assert the validity of the choice of indicators for assessing the impact of social and economic indicators on the processes of innovation and digital transformation. The initial data were imported into the JASP statistical software to obtain the regression analysis results and build a model for forecasting Ukraine's further digital adaptation. A general description of the regression model is presented in Table 5.

Table 5

General Characteristics of the Regression Model

Model Summary - Score				
Model	R	R^2	Adjusted R^2	RMSE
M_0	.99	.99	.98	3.65
M_1	.99	.99	.99	2.09
M_2	1.00	.99	.99	2.34

*Note. * p< .05; M0 includes the Human Capital Index, the E-Participation Index; M1 includes the E-Governance Development Index, Online Services Index, Telecommunications Infrastructure Index; M2 includes Human Capital Index, E-Participation Index, E-Governance Development Index, Online Services Index, Telecommunications Infrastructure Index*

Given the data, the M_1 model is the most optimal for predicting digital adaptability, as economic factors have a more precise and more substantial impact on this indicator, mainly due to the high level of correlation (R = .99) and explanatory power (R^2 = .99). In contrast, the model demonstrates high forecast accuracy (RMSE = 2.09). In contrast, the model that takes into account only social indicators (M_0), although fully explaining the development of digital adaptability (R = .99; R^2 = .99), needs to improve its prediction accuracy in future studies (RMSE = 3.65), for example, by adding other variables. The model that considers all possible variables (M_2) allows us to view the factors affecting digital adaptability. This model indicates benchmark correlation (R = 1) and explanatory power (R^2 = .99). However, the value of the modification of the standard R^2 (Adjusted R^2 = .99) and the root mean square error (RMSE = 2.34) indicate that the inclusion of additional variables may lead to a slight decrease in forecast accuracy due to possible inter-variable correlations or excessive model complexity. Given the high correlation between the independent variables in the regression model, which can lead to problems in estimating the model parameters, an increase in standard errors and a decrease in the reliability of the regression coefficients, we performed a multicollinearity diagnosis, the results of which are presented in Table 6.

Table 6

Diagnosing Multicollinearity for Regression Models

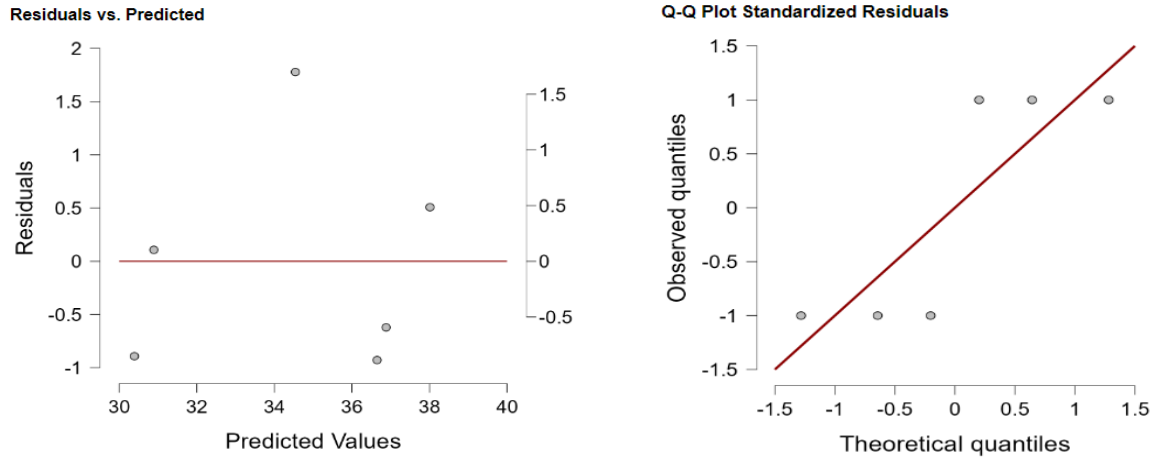
Collinearity Diagnostics								
				Variance Proportions				
Model	Dimension	Eigenvalue	Condition Index	Online services index	E-government development index	Human capital index	E-participation index	Telecommunications infrastructure index
	HCI	1.96	1.00			0.01	0.01	
M_0	EPART	0.03	7.79			0.98	0.98	
	TII	2.98	1.00	0.00	0.00			0.00
	OSI	0.01	15.81	0.75	0.54			0.00
M_1	EGDI	0.00	19.96	0.24	0.45			0.99
	HCI	4.90	1.00	0.00	0.00	0.00	0.00	1.48
	EPART	0.06	8.59	0.00	0.00	0.00	0.00	7.35
	TII	0.02	13.62	0.00	0.00	0.00	0.41	3.54
M_2	OSI	0.00	33.39	0.00	0.00	0.00	0.55	2.88
	EGDI	2.123×10^{-10}	151981.62	1.00	1.00	1.00	0.03	0.99

In the case of the M_0 model, the low of the Condition Index, which does not exceed .5, indicates no problems with multicollinearity between the social independent variables. While the corresponding index for M_1 has high values, the proportions of variation do not show significant correlations, indicating moderate multicollinearity between the economic variables. In turn, the model that takes into account all possible variables (M_2), having high values of the Condition Index and, therefore, strong linear relationships between the variables, indicates problems with multicollinearity, as there is a large proportion of variation for some variables (in particular, OSI and EGDI). Therefore, the identified problems with multicollinearity in the M_2 model, which potentially impact the estimates' accuracy and the assumed stability of the results, prompt additional model checks.

The next step in ensuring the quality of the model was a two-stage check based on the regression analysis results, as shown in Figure 4.

Figure 4

Estimation of the Residual Characteristics of the General Regression Model



a) Graph to test for homoscedasticity

b) Graph to check the normality of the residuals

Given the high values of R^2 found; to test the model for violations of the assumption of constant variance of the residuals, we generated a graph of Residuals vs. Predicted using the JASP statistical software. In general, the graph does not show any trends or patterns, i.e., we believe that the values are evenly distributed over the entire range of predicted values, indicating no homoscedasticity problems. Instead, we generated a Q-Q Plot Standardised Residuals graph to check the normality of the model residuals. The resulting graph does not show any significant deviations, having two corresponding straight lines, and, therefore, should be considered normally distributed.

Discussion

McMillan et al. (2017) and Weldegiorgis et al. (2022) argue that economic transformation is a dynamic process of structural change associated with reallocating resources in directions that can increase overall productivity. Lin (2017), Ing and Lin (2024), and Yudhoyono et al. (2024) also share a similar view on the importance of resource potential for economic growth. Our results confirm the above opinion, as the M_1 model based on economic indicators shows the most precise and substantial impact on digital adaptability ($R = .99$, $R^2 = .99$), indicating the key role of economic factors in digital adaptation. In turn, Peláez et al. (2022) and Colomo-Magaña et al. (2024) emphasise the impact of digital transformation on society, including developing digital skills and inclusiveness. In our study, the social variables have a high correlation ($R = .99$) and explanatory power ($R^2 = .99$), which indicates their significance and confirms the findings of the above authors on the impact of digitalisation. However, Li and Kostka (2024) noted that the digital divide remains an important limitation of digital adaptation that requires further advanced research. In turn, Bilan et al. (2023) and Maikomo et al. (2021) point to digital technologies' economic and social adaptability in preventing and addressing the consequences of crises. Given the close to the benchmark values of the correlation ($R = 1$) and explanatory power ($R^2 = .99$) of the M_2 model, which includes all possible variables, we should agree with these authors on the need for an integrated approach to taking into account various factors of digitalisation. In addition, the graphs of the residuals and their distribution (Q-Q Plot Standardised Residuals) also indicate a high level of model stability, which allows us to conclude that the results obtained are reliable and that the study's conclusions are valid.

Conclusion

Given that digital adaptation is a key element of Ukraine's development in the context of war, globalisation challenges and technological innovation, its effectiveness significantly impacts economic and social stability, facilitating Ukraine's integration into the global digital space. However, the level of digital adaptation in Ukraine remains uneven, and to achieve sustainable progress, it is necessary to focus on further developing digital infrastructure, enhancing institutional capacity, and ensuring the integration of digital services into all sectors of the economy. The results of this study confirm that Ukraine's digital adaptation has significant potential to improve the economic situation and enhance social inclusion in the context of global digitalisation. To ensure a steady increase in the efficiency of digital adaptation, despite the high correlation and explanatory power of all regression models, further research is needed to reduce multicollinearity and refine forecasting models.

Declarations

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