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Determinants of Digital Economy Development in the EU Member States: The Role of Technological Infrastructure, Human Capital, and Innovation

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Abstract

Motivation: The rapid digital transformation in the European Union has highlighted the increasing importance of the digital economy in shaping national competitiveness. Recent studies underline the relevance of innovation, human capital, and digital infrastructure as critical factors driving digitalisation. Despite extensive literature on digital economy development, there is a gap in understanding the specific determinants that influence the digitalisation levels across EU member states. This study addresses this gap by examining the relationship between digital infrastructure, human capital, and innovation in fostering digital growth, using the Digital Economy and Society Index (DESI) and European Innovation Scoreboard (EIS) as key indicators.
Aim: The aim of this research is to identify and quantify the key determinants influencing the development of the digital economy in the EU member states between 2017 and 2022. Specifically, the study investigates the impact of technological infrastructure, human capital, and intellectual assets on the digital economy. By employing multiple linear regression models, the research aims to clarify how these factors contribute to digital economy growth.
Results: The analysis revealed that technological infrastructure and use of information technology are consistently the most significant determinants of digital economy development. Human capital, particularly in terms of education and digital skills, gained importance in the later years of the study. Intellectual assets, such as patents and research outputs, also played a critical role, particularly from 2021 onwards. The findings suggest that countries with robust digital infrastructure, well-educated workforces, and strong innovation ecosystems tend to perform better in terms of digitalisation, as measured by DESI. These insights provide valuable guidance for policymakers aiming to enhance digital competitiveness through targeted investments in technology, education, and innovation.

Keywords: digital economy; human capital; digital infrastructure; country innovation level; Digital Economy and Society Index (DESI); European Innovation Scoreboard (EIS)
JEL: O30; O50; C30

1. Introduction

In today's global economy, a high degree of digitalisation is essential for shaping competitive advantages at individual, corporate, sectoral, and national levels. The digital economy, characterised by the integration of digital technologies, has a significant impact on economic activities and competitiveness at both micro and macro levels (Schwab, 2017; Roszko-Wójtowicz & Białek, 2016). Digitalisation not only extends economic activities globally but also creates new value, crucial for sustaining competitiveness across diverse sectors (Brynjolfsson & McAfee, 2014). The development of digital platforms and applications is reshaping market processes, increasing operational efficiency, and creating new business opportunities (Parker et al., 2016). Moreover, digital transformation fundamentally changes business operations and value delivery, impacting governance, commerce, and the knowledge society (Tapscott, 1996). These transformations also bring about organisational changes, enhancing companies' abilities to adapt and use digital technologies for economic and social purposes (Morrar et al., 2017). Hence, the shift is not merely technological but also organisational, bolstering digital competitiveness (Westerman et al., 2014). State policy thus plays a pivotal role, as effective policies in the digital economy are vital for boosting national competitiveness and addressing the challenges posed by digitalisation (Porter & Heppelmann, 2015). Consequently, the interplay of digitalisation, transformation, and state policy is essential for leveraging competitive advantages in the contemporary economic landscape (Castells, 2010; Roszko – Wójtowicz & Grzelak, 2020). Given the complexity and speed of change in the economy, particularly with increasing digitalisation of socio-economic life, there is a need to identify the dependencies and determinants crucial to building each country's digital economy. This is influenced not only by countries' digital readiness but also by policies at regional, national, and international levels (UNCTAD, 2019).

In recent years, the link between innovation and economic competitiveness has become prominent, drawing attention to the importance of digitalisation (e.g., Grynia, 2022). Many researchers (e.g., Sorescu & Schreier, 2021; Yang & Tan, 2023) highlight a strong relationship between innovation and the digitalisation of the economy. Sorescu and Schreier (2021) emphasise that innovation, especially in technology, drives the digital economy, encompassing the development of new products, services, processes, and business model innovations. Technology linked to the digital economy has expanded the boundaries of innovation, enabling new types and avenues for developing and disseminating innovations.

The presented research aimed to identify key factors relevant to digital economy development. In the theoretical section, the article presents a conceptualisation of the digital economy through definitions. The literature review subsequently identifies research areas central to the study of digital economy growth. In the empirical section, the authors selected indicators that reflect the literature review findings. The operationalisation process aimed at statistically verifying the relationship between factors deemed significant for economic innovation (drawing on data from the European Innovation Scoreboard) and their relevance to digital economy growth. Covering all EU Member States, the study developed linear regression models for each year between 2017 and 2022. Recognising the importance of technological infrastructure and human capital potential, including education, skills, and creative activities (e.g., patents), the regression models used selected indicators to assess innovation levels in the economy (following EIS methodology) to empirically verify their connection to digital economy development.

The findings indicate that technological infrastructure and technology usage are key determinants of digital economy growth. Human capital, alongside access to technology, also grows increasingly important, particularly in terms of skills and creative potential, which can influence the further development of a country's digital economy. The conclusions offer valuable insights for policymakers in planning and implementing effective digital policies to enhance national economic competitiveness.

2. Literature review – Digital Economy – Definitions and Conceptualisation

As digital transformation progresses, business processes are evolving. Today, economic competitiveness is closely tied to digitalisation's extent, both qualitative and quantitative. Global organisations, including the IMF (2023, p. 140), highlight not only the relevance but also the complexity of the 'digital economy,' noting that 'digitalisation is affecting the production, ordering, delivery, and consumption of many goods and services,' to the extent that modern economies are now essentially 'digital economies.'

According to Fuior and Zavatki (2022), the digital economy began in the late 1950s with business process automation technologies, such as IBM and American Airlines' SABRE system in 1960, which automated airline bookings. The next wave came in the 1970s with electronic trading, followed by the advent of the web, marking a turning point. Web 2.0 enabled user-generated content, driving social networks' growth, while Web 3.0 improved data transmission speeds, allowing multimedia sharing. Currently, Web 4.0 is associated with smart grids (Śledziewska et al., 2017), and these advancements have transformed business operations, enabling large-scale data analysis and automation (Śledziewska et al., 2017).

One of the earliest Internet economy concepts emerged in the late 1990s with McKnight and Bailey's (1998) work. Terms such as 'network economy' and 'digital economy' evolved alongside technology growth and demand. Definitions of the digital economy have varied, some focusing on technology's role, others on the importance of network types. Scholars (e.g., Jakubelskas, 2021; Bukht & Heeks, 2017) underline its multidimensional nature, distinguishing the Core: Digital (IT/ICT) Sector, Narrow Scope: Digital Economy, and Broad Scope: Digitalised Economy (Scheme 1). In 2020, the OECD described the digital economy which '*incorporates all economic activity reliant on, or significantly enhanced by the use of digital inputs, including digital technologies, digital infrastructure, digital services and data. It refers to all producers and consumers, including government, that are utilising these digital inputs in their economic activities.*' (OECD, 2020b. p.5).

Research on measuring the digital economy includes studies on national economies (e.g., Lazăr, 2021; Jurcevic et al., 2020; Cseh-Zelina, 2023), groups of countries (e.g., Jencova et al., 2023; Janevski, 2017), and international comparisons of specific digital economy areas. Commonly, these take the form of aggregated indices or analyses from organisations such as the EU (DESI), OECD (Going Digital Toolkit), World Bank (Digital Adoption Index), and IMD (World Digital Competitiveness Ranking). Relevant to this study, DESI summarises Europe's digital progress in four dimensions outlined in the Digital Decade policy: digital skills, infrastructure, business digitalisation, and public services. Many researchers (e.g., Zaharia & Bălăcescu, 2020; Cesnauske, 2019; Parra et al., 2021; Bánhidi et al., 2020; Moroz, 2017; Borowiecki et al., 2021) have evaluated the digital economy's development in the EU Member States using DESI scores. Jenčová et al. (2023) found statistically significant correlations in EU country rankings, identifying internally homogeneous and externally heterogeneous country clusters based on DESI scores.

Bánhidi et al. (2020) examined DESI's five dimensions with multivariate statistics, analysing linear relationships through correlation and partial correlation analyses, revealing high inter-dimensional correlations. They used cluster analysis and multidimensional scaling to group the EU countries, comparing these results to DESI's overall ranking, which confirmed DESI's usability and effectiveness. In summary, while the EU Member States exhibit disparities and heterogeneity in digital economy development, relatively few studies have focused on identifying the specific factors that drive or support this growth. This study aims to address that research gap.

2.1. The potential of human capital and technological infrastructure – factors supporting the development of the digital economy

The link between innovation and digitalisation in the economy is evident in global rankings such as EIS, RIS, and GII, which assess countries by innovation levels. Increasingly, these indices integrate digital skills and ICT indicators, such as ICT access, usage, online government services, and ICT trade, reflecting the broader impact of digitalisation on economic competitiveness (Roszko-Wójtowicz et al., 2022). Studies on ICT and innovation relationships include examining IT investments' impact on innovation outcomes (Orozco et al., 2022), ICT development in the EU-28 (Preda et al., 2019), and ICT's role in enterprise innovation (Wang & Qi, 2021).

Yang and Tan (2023), using R-tool bibliometric analysis, found that innovation consistently appears in academic research as a primary driver of the digital economy, with implications for policymakers to prioritise innovation in digital economy strategies.

The digital economy's complexity makes it challenging to outline a universal set of growth factors. However, a foundational requirement is robust technological infrastructure, covering telecommunications and high-speed internet access. Since the digital economy relies on extensive online interactions among individuals, businesses, devices, and data, connectivity is essential (Sorescu et al., 2021). Research also highlights that broadband, internet usage, and e-commerce contribute to economic growth in the EU (Petrić et al., 2020).

Kiseľáková et al. (2022) emphasise that digital skills and human capital, along with technology integration, are core to digital transformation and economy development. Studies at the regional level further show the interconnected growth of digital economy, innovation, and human capital, especially through higher education (Szeles et al., 2020). Skilled labour is critical for leveraging digital economy potential, as employees with digital expertise enable advanced technology adoption in daily operations (Majovski & Davitkovska, 2017). Global studies by institutions such as the World Bank, WEF, and OECD stress that an educated society promotes a more efficient, productive workforce (Espinel, 2016; Vasilescu et al., 2020; OECD, 2020a; OECD, 2020b).

Thus, education's role in supplying a skilled workforce is vital not only for the labour market but also for comprehensive strategies in digital economy development. Numerous studies have explored education's importance in digital transformation (Švarc et al., 2021; Jakubelskas, 2021; Donosa, 2021). Today, higher education is closely linked with science; as Smith (2020) from the OECD notes, public sector science remains foundational to the digital revolution. The World Wide Web, initially developed for particle physics at CERN, exemplifies science's role in advancing digital technology. Academic research, from quantum computing to biological data storage, continues to fuel new digital technology (Smith, 2020). Universities, research institutions, and doctoral studies contribute to innovative digital solutions.

Digital transformation has intensified the demand for a digitally skilled workforce. ICT investments and hiring specialised workers are key to advancing business digital transformation (Vasile, 2023). Similarly, Tran et al. (2024) emphasise that digital skills and ICT professionals are vital for successful digital transformations, while Bach et al. (2020) underscore the need for businesses to invest in employee ICT training to support digital economy growth in Europe.

The rapid pace of socio-economic change reinforces the need for continuous skills enhancement, not just within ICT. Lifelong learning, long tied to ongoing skill development, now extends to the digital domain. 21st-century skills go beyond digital proficiency, encompassing ethical and cultural awareness, flexibility, and self-direction (van Laar, 2017). Researchers such as Jaldemark (2021), Gleason (2019), and Laal (2013) highlight that lifelong learning enables individuals to adapt to technological changes, essential for digital economy survival and growth.

3. Data and characteristics of countries in terms of the issues studied

An analysis of the Summary Innovation Index (SII) and Digital Economy and Society Index (DESI) data from 2017–2022 reveals essential connections between innovation and the digital economy's growth. This article examines European countries based on their SII and DESI rankings and the changes over time, confirming that countries leading in innovation often achieve higher levels of digitalisation (Figure 1, Figure 2). The analysis and assessment of changes over time are based on available and published data on the SII, DESI and sub-indices included in their construction. Heat maps illustrate changes in DESI and SII values in a spatial-temporal system. They serve to visualise SII and DESI data presented in the paper through differences in colour, according to the legend, red indicates the highest values.

Countries such as Denmark, Finland, Sweden, and the Netherlands score highly in both SII and DESI. Denmark, for instance, consistently ranks high in both indices, highlighting a strong correlation between innovation and digitalisation. These innovation leaders facilitate the swift adoption and integration of digital technologies within their economies. Their digital infrastructure benefits from progressive policies promoting research and development, making innovation a driver of digital economy growth as reflected in DESI scores (Figure 1, Figure 2).

Once technological infrastructure reaches a saturation point, further DESI progress depends increasingly on citizens' creativity and innovation capabilities. Human potential enables the effective use of infrastructure to foster new technological solutions, crucial for enhancing the digital economy. These countries also significantly invest in education and the development of societal adaptability, supporting their digital economies.

Luxembourg illustrates the link between innovation and digitalisation differently; despite high SII levels, its DESI scores have not notably advanced since 2019, implying other factors might constrain full digital development. Ireland, too, has improved in SII, which could positively influence its DESI position in the long term, despite a temporary decline in the DESI ranking. Upon reaching a saturation level in technological infrastructure, further digitalisation steps hinge on human potential, which Ireland leverages effectively.

The study highlights exceptions where high innovation does not necessarily lead to strong DESI scores. Estonia and Cyprus maintained steady DESI scores but saw declines in SII, suggesting that insufficient innovation may weaken the digital economy if new technological solutions are not introduced. Estonia's high DESI ranking may suffer from a fall in innovation, as technological advancements are essential for continued digital growth. The data suggest that while strong innovation generally supports digital economy development, other factors can limit its full potential (e.g., in Luxembourg and Estonia). Figure 3 confirms the existence of a strong positive correlation between the level of the digital economy and the country's level of innovation. Moreover, apart from very few cases, a high level of innovation does not occur in countries where the DESI indicator is relatively low (the bottom right corner in the correlation scatter diagrams). Correlation scatter diagrams illustrate the relationships between SII and DESI in the subsequent years of analysis—2017–2022.

An analysis of the changes in key DESI factors from 2017 to 2022 yields the following conclusions, further reinforcing the role of innovation and human capital:

1. Human Capital Growth and DESI Impact: Belgium, Cyprus, and Croatia recorded substantial growth in their Human Resources index, improving their DESI scores. Increased human potential, measured in education and digital skills, is critical for advancing digitalisation. Cyprus, for example, improved its 'Human Resources' by 9.8 points and DESI by 19.2 points, showing that human capital investment accelerates the digital economy, especially when infrastructure reaches saturation.

2. Digitalisation as a Key Factor, Though Not Solely Sufficient: The Digitalisation index rose in most countries during the study period, but its impact on DESI was greatest when combined with other factors such as human resources and intellectual assets. Croatia and Cyprus, which saw notable increases in both 'Digitalisation' and 'Human Resources,' also achieved the highest DESI gains (17.17 and 19.20 points, respectively), suggesting that digitalisation's effectiveness is enhanced by a well-educated, innovative workforce.

3. Decline in Technology Use in Some Countries: Austria and Belgium saw declines in the 'Use of Information Technology' index, which may indicate that digital infrastructure investments alone are insufficient if companies and institutions do not fully utilise available technology. In Austria, despite this decline, DESI scores rose by 18.3 points due to growth in human resources and intellectual assets.

4. Intellectual Assets' Role in Digitalisation: Intellectual Assets, measuring technological innovation and intellectual property protection, had mixed impacts on DESI. In Bulgaria and Cyprus, declines in intellectual assets did not offset DESI increases, indicating that in some countries, investments in human capital and digital technologies are more crucial than intellectual property protection.

Countries investing in human capital development, such as Cyprus, Croatia, and Belgium, experience significant DESI gains, illustrating that when technological infrastructure is saturated, further digital growth increasingly relies on human resources' quality, particularly in education, digital skills, and creativity. While digitalisation is essential for economic development, its effectiveness is closely tied to human resources and the capacity to innovate.

4. Methods

The digital economy, seen as a crucial factor in enhancing economic efficiency, draws growing interest from economists and practitioners alike. Recognised for fostering competitiveness at individual, corporate, sectoral, and national levels, a high degree of economic digitalisation is key in the global landscape.

However, there is still a lack of research on the nature and comprehensive coverage of the digital economy. This is probably due to the complexity, multidimensionality and dynamics of this phenomenon. An important aspect of the research should be, on the one hand, to measure the level and sophistication of the digital economy and, on the other hand, to isolate the relevant drivers of the digital economy.

This study attempts to fill the gap in the analysis of the links between the digital economy and the factors determining its growth. In the article, against the background of theoretical economic considerations, the theses put forward are verified using quantitative methods, including linear regression. The object of the presented research is to determine the quantitative relations occurring between selected factors influencing the development of the digital economy (independent variables) and the level of the digital economy (dependent variable).

The analysis used data from international studies on EU digitalisation, specifically from the Digital Economy and Society Index (DESI) and the European Innovation Scoreboard. The Digital Decade Policy Programme 2030, established by Decision (EU) 2022/2481 in December 2022, formalised DESI as a comprehensive metric for annually tracking digital performance across the EU, monitoring progress toward EU-wide digital goals. This research spans 2017–2022, with linear regression models built yearly to provide insights relevant for pre-2030 digital policy recommendations. DESI served as the dependent variable for measuring digital economy levels within the EU countries.

Following Sorescu & Schreier's (2021) view that innovation drives the digital economy, this study selected explanatory variables reflecting the economy's innovativeness. These variables are sub-indices from the Summary Innovation Index, covering aspects of innovation and digitalisation: 1.1 Human resources, 1.2 Attractive research systems, 1.3 Digitalisation, 2.1 Finance and support, 2.2 Firm investments, 2.3 Use of information technologies, 3.1 Innovators, 3.2 Linkages, 3.3 Intellectual assets, 4.1 Employment impacts, 4.2 Sales impacts, and 4.3 Environmental sustainability.

The study aimed to identify which sub-indices have the most significant impact on DESI and how their influence has evolved. The final selection of determinants was supported by literature and statistical analyses. In structural modelling, sub-indices with strong correlations to DESI over time, but minimal correlation with each other, were used as independent variables. These included: Human resources (X1); Attractive research systems (X2); Digitalisation (X3); Finance and support (X4); Use of information technologies (X5); Linkages (X6); Intellectual assets (X7); and Employment impacts (X8).

In search of the best analytical form, nonlinear and linear models were tested. Finally, linear models, fulfilling the Markov assumptions and taking into account all potential explanatory variables, were selected:

$$Y1it=\beta 0+ +\beta 1x1+\beta 2\,x2 +\beta 3\,x3 +\beta 4\,x4 +\beta 5\,x5 +\beta \ldots+ \varepsilon it \qquad (1)$$

where:

x1: Human resources;
x2: Attractive research systems;
x3: Digitalisation;
x4: Finance and support;
x5: Use of information technologies;
x6: 3.2 Linkages;
x7: Intellectual assets;
x8: 4.1 Employment impacts.

Structural parameters were estimated using the CLS method (Classical Least Squares Method). It was assumed that a good model was one containing only statistically significant variables. In the process of constructing the ‘optimal’ model, a stepwise method was used, successively excluding variables that proved to be insignificant. It was recognised that with too many independent variables (including irrelevant ones), there is a risk of excessive collinearity, the introduction of unnecessary information (noise) into the model, and unintended loss of degrees of freedom. The variance of the model parameters then increases, and it becomes more difficult to interpret the strength of the effect of the independent variables on the dependent variable (Maddala, 2008).

5. Results

The estimation results of the DESI models, the best from both the substantive and statistical perspectives, are presented in Table 1. The multiple linear regression models presented below were obtained using the stepwise method in the Gretl programme.

The models presented satisfy the Markov assumptions and are statistically and substantively correct. The correctness of the model specification was confirmed by the RESET test. The collinearity of the independent variables was tested using the VIF coefficient. The normality of the distribution of the random component was verified with the Shapiro-Wilk test, and the hetroscedaticity of the residuals with the White test.

The models are sufficiently well fitted to the empirical data. This is evidenced by significantly greater than zero values of the coefficients of determination (the probabilities in the Anova test are less than 0.05). The estimated structural parameters are as expected and the models are cointegrated, the signs of the parameters being the same as in the correlation coefficients of the independent variables with the dependent variable.

In the presented linear regression models (Table 1), in which the dependent variable is the DESI (Digital Economy and Society Index), the results obtained clearly indicate a significant impact of digitalisation (X3) – represented by by broadband penetration and iIndividuals who have above basic overall digital skills – and the use of information technology (X5) – represented by enterprises providing training to develop or upgrade ICT skills of their personnel and employed ICT specialists – on the development of the digital economy in the European Union countries. In each of the years analysed (2017–2022), the 'Digitalisation' and 'Use of Information Technology' variables proved to be statistically significant, confirming their crucial importance in shaping the DESI level.

In 2017, the 'Digitalisation (broadband penetration and individuals who have above basic overall digital skills)' and 'Use of Information Technology (enterprises providing training to develop or upgrade ICT skills of their personnel and employed ICT specialists)' variables have a significant impact on the DESI, and the value of the coefficient of determination indicates that the model explains a high degree of the variability of the DESI. The model explains 81.19% of the variation in the DESI, indicating a strong relationship between the explanatory variables for digitalisation and the development of the digital economy in the EU in that year (Table 1). For the next three years (2018, 2019 and 2020), the DESI modelling results are very similar to 2017. The coefficients of 'Digitalisation' and 'Use of Information Technology' remained significant, the estimated values of the regression coefficients were positive and similar in value. The models explained 81.01% (2018) and 80.43% (2019) and 84.35% (2020) of the variation in the DESI, respectively. In 2021, a new situation was observed in the DESI model. The independent variable 'Human Resources' – represented by new doctorate graduates (in STEM), population aged 25–34 with tertiary education and lifelong learning was also found to be statistically significant, as were 'Digitalisation' and 'Use of Information Technology.' The model for 2021, with the new explanatory variable, is characterised by a better fit of the regression function to the empirical data. The coefficient of determination reached 0.873233, meaning that the model explained 87.32% of the variation in the DESI. All independent variables were statistically significant, and tests for model specification, heteroskedasticity and normality of residuals confirmed its validity and compliance with the assumptions of linear regression. In 2022, another factor appeared in the model, the fourth independent DESI variable. The 'Intellectual Assets' variable – represented by PCT patent applications, trademark applications and design applications – like the DESI descriptor variables included so far, is statistically significant. The DESI model for 2022 with the new explanatory variable 'Intellectual Assets' is characterised by strong predictive ability, with a coefficient of determination of 87.53%. Diagnostic tests, as in the models for previous years, confirmed that the model is substantively and statistically correct (Table 1).

In conclusion, the results of the research conducted for the years 2017–2022 indicate that technological infrastructure and the use of information technology are key determinants of the development of the digital economy in the EU countries. Human Resources and Intellectual Assets are also important determinants of DESI development. The high values of the coefficient of determination (adjusted R-squared) in the years analysed demonstrate the strong ability of the models to explain the variability of the DESI, which is in line with the literature that emphasises the importance of digitalisation, human capital and intellectual assets in the development of the digital economy. These results are consistent with previous studies that point to the multidimensional nature of the digital economy and its dependence on advanced technological infrastructure and highly skilled human capital. Understanding these dependencies is key to formulating effective policies to support the further development of the digital economy in the European Union.

6. Discussion

Research by Olczyk and Kuc-Czarnecka (2022) on the DESI index reveals that the 'Connectivity' dimension has the most substantial impact on digital transformation across the EU Member States. Rapid ICT progress is closely linked to economic growth, showing a positive correlation with GDP (Magoutas et al., 2024). Within this framework, the 'Digitalisation' and 'Use of Technology' sub-indices, both identified as statistically significant, are particularly important. The 'Digitalisation' sub-index includes 'Broadband penetration,' indicating enterprises with fixed Internet speeds of at least 100 Mbps (European Commission, 2022). Meanwhile, the 'Use of Technology' sub-index underscores the value of ICT specialists and enterprises offering ICT training to employees (European Commission, 2022). This research thus supports the view that ICT skills are 'particularly important for innovation in an increasingly digital economy' (European Commission, 2022, p. 95).

Studies of OECD economies further highlight ICT's positive impact, recommending policies to strengthen ICT infrastructure, enhance digital skills, and promote equitable ICT access (Gomes et al., 2022). However, the OECD also notes that hiring ICT professionals does not always benefit economic development, given the lengthy, costly training required. Additionally, without mechanisms to retain talent domestically, government investments in ICT training can suffer if trained professionals emigrate (Petrić et al., 2020). High industry profitability, growth opportunities, and potential earnings in ICT draw workers from other sectors, potentially disrupting the labour market (Petrić et al., 2020).

Nevertheless, as Xia et al. (2024, p. 1) argue, the digital economy has evolved into an innovation-led economy using digital technology and communications across sectors such as e-commerce, digital marketing, fintech, software, gaming, and cloud services.

Liu Chao and Liu Di (2024) emphasise the importance of information and communication technologies (ICT) in supporting economic growth, particularly in developed economies. They also highlight the necessity of implementing public policies that support both physical infrastructure and the use of ICT. Consequently, it is crucial to view digitalisation as a key driver of economic growth.

Research aimed at identifying the most significant determinants of digital technology development at the macro level seeks to provide recommendations for national and regional economic systems (Buyanova et al., 2022; Dworak et al., 2022).

Regional studies confirm that higher education growth and patent filings stimulate regional digital economy development (Szeles et al., 2020). Similarly, findings in this publication suggest that human capital and technology access are increasingly vital, particularly in skill levels and creative potential, for advancing a country's digital economy. 'Human Resources' and 'Intellectual Assets' sub-indices were statistically significant; these indicators consider factors such as tertiary education levels, lifelong learning participation (Human Resources), and patent filings (Intellectual Assets). Many studies show that educated populations are better equipped to adopt digital technologies, thus fostering digital economy growth (Espinel, 2016; Vasilescu et al., 2020; OECD, 2020a; OECD, 2020b). Furthermore, advanced education generally correlates with enhanced digital skills, which are essential for tech-sector employment (Vasilescu et al., 2020).

Majovski and Davitkovska (2017) underscore that enhancing digital skills is now a priority for both companies and national economies, as digital and entrepreneurial skills together create future opportunities to work in tech-rich environments and leverage technology-driven business innovations.

7. Conclusion

The research aimed to pinpoint key factors driving digital economy growth in the EU Member States between 2017 and 2022. Using data from the Digital Economy and Society Index (DESI) and the European Innovation Scoreboard, the study identified strong relationships between digitalisation, IT use, human capital, and intellectual assets as crucial to advancing the digital economy. Multiple linear regression models showed that digitalisation and IT use were consistently fundamental to growth across the EU countries throughout the period.

In the later years (2021–2022), human capital—specifically, an educated and skilled workforce—emerged as increasingly vital. This finding underscores the growing awareness that a thriving digital economy depends not only on infrastructure but also on individuals' ability to adapt, innovate, and utilise digital tools. Intellectual assets such as patents and research outputs also became critical, suggesting that economies oriented toward innovation are better equipped to capitalise on digitalisation.

The findings support the hypothesis that economies with advanced infrastructure, high educational levels, and strong innovation ecosystems are more likely to nurture a successful digital economy. These insights guide policymakers to emphasise digital infrastructure, educational advancement, skill development, and environments fostering innovation. Such strategies can help sustain and speed up digital transformation, enhancing competitiveness in an increasingly digital world.

Despite these insights, the study has limitations. The scope of data was confined to DESI and European Innovation Scoreboard indicators, which, while comprehensive, may not capture all growth-influencing factors, such as regional disparities, socio-economic conditions, or private sector investment. Future studies should incorporate these variables for a more nuanced understanding. Moreover, as the study focused solely on the EU Member States, the results might not directly apply to non-EU countries with different institutional and regulatory conditions impacting digitalisation and economic growth.

Future research could explore specific digital economy sectors such as e-commerce, fintech, and digital services to understand unique sectoral dynamics. Longitudinal studies extending beyond 2022 are also necessary to observe the evolving impact of emerging technologies, such as AI, blockchain, and 5G, on digital economy development. Given the rapid pace of technological change, further research should examine how countries can adapt and remain resilient to the challenges and opportunities posed by such innovations.

In conclusion, this study contributes valuable knowledge to the digital economy literature but also points to the need for ongoing research to fully capture the complexities and continuous evolution of digital transformation. Policymakers must adopt flexible approaches, adapting strategies as technological advancements emerge to ensure that the benefits of the digital economy are broadly distributed across all sectors of society.

While this study provides a foundation for future work, further exploration is needed to understand the full range of factors driving digital economy success, particularly as new technologies reshape the global economy.

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Appendix

Table 1. DESI model parameter estimation results

Model 6 (2017)					
Variable	**Coefficient (B)**	**Standard Error**	**t-Statistic**	**p-value**	**95% Confidence Interval**
Constant (const)	15.4095	2.0893	7.375	<0.0001	[11.2105; 19.6085]
Digitalisation	0.1113	0.0252	4.416	0.00002	[0.0593; 0.1632]
Use of Information Tech.	0.0761	0.0199	3.817	0.00008	[0.0349; 0.1172]
Model statistics					
Adjusted R-squared	0.7962				
Residual sum of squares	298.2055				
Standard error of residual	3.524944				
Akaike information criterion	147.4752				
Bayesian information criterion	151.3627				

Model 6 (2018)					
Variable	**Coefficient (B)**	**Standard Error**	**t-Statistic**	**p-value**	**95% Confidence Interval**
Constant (const)	16.8302	2.1840	7.706	<0.0001	[12.3026; 21.3578]
Digitalisation	0.1175	0.0264	4.452	0.00002	[0.0630; 0.1719]
Use of Information Tech.	0.0772	0.0207	3.730	0.00010	[0.0345; 0.1199]
Model statistics					
Adjusted R-squared	0.7943				
Residual sum of squares	326.8851				
Standard error of residual	3.690557				
Akaike information criterion	149.9545				
Bayesian information criterion	153.8420				

Model 6 (2019)					
Variable	**Coefficient (B)**	**Standard Error**	**t-Statistic**	**p-value**	**95% Confidence Interval**
Constant (const)	18.3983	2.3196	7.932	<0.0001	[13.5983; 23.1983]
Digitalisation	0.1270	0.0272	4.672	<0.0001	[0.0709; 0.1831]
Use of Information Tech.	0.0775	0.0216	3.579	0.00015	[0.0328; 0.1222]
Model statistics					
Adjusted R-squared	0.7880				
Residual sum of squares	362.9733				
Standard error of residual	3.888944				
Akaike information criterion	152.7820				
Bayesian information criterion	156.6695				

Model 6 (2020)					
Variable	**Coefficient (B)**	**Standard Error**	**t-Statistic**	**p-value**	**95% Confidence Interval**
Constant (const)	19.2468	2.2188	8.674	<0.0001	[14.7094; 23.7842]
Digitalisation	0.1338	0.0259	5.158	<0.0001	[0.0803; 0.1874]
Use of Information Tech.	0.0886	0.0211	4.205	0.00003	[0.0451; 0.1321]
Model statistics					
Adjusted R-squared	0.8305				
Residual sum of squares	325.4991				
Standard error of residual	3.682725				
Akaike information criterion	149.8398				
Bayesian information criterion	153.7273				

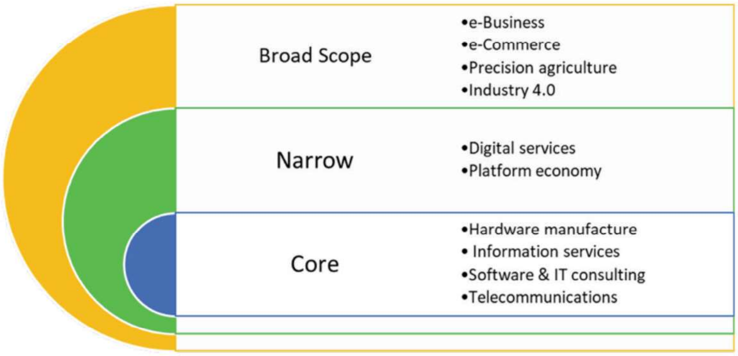
Model 6 (2021)					
Variable	**Coefficient (B)**	**Standard Error**	**t-Statistic**	**p-value**	**95% Confidence Interval**
Constant (const)	22.9469	2.2470	10.21	<0.0001	[18.4531; 27.4407]
Human Resources	0.0734	0.0348	2.110	0.0460	[0.0014; 0.1454]
Digitalisation	0.0827	0.0345	2.399	0.0249	[0.0114; 0.1540]
Use of Information Tech.	0.0798	0.0284	2.807	0.0100	[0.0210; 0.1387]
Model statistics					
Adjusted R-squared	0.8567				
Residual sum of squares	315.5773				
Standard error of residual	3.704153				
Akaike information criterion	151.0040				
Bayesian information criterion	156.1873				

Model 6 (2022)					
Variable	**Coefficient (B)**	**Standard Error**	**t-Statistic**	**p-value**	**95% Confidence Interval**
Constant (const)	25.4232	26.0451	9.761	<0.0001	[0.0006; 50.8458]
Human Resources	0.0655	0.0351	1.866	0.0755	[-0.0062; 0.1372]
Digitalisation	0.0860	0.0339	2.536	0.0188	[0.0163; 0.1557]
Use of Information Tech.	0.0572	0.0311	1.836	0.0798	[-0.0061; 0.1205]
Intellectual Assets	0.0605	0.0322	1.881	0.0733	[-0.0055; 0.1261]
Model statistics					
Adjusted R-squared	0.8526				
Residual sum of squares	315.4819				
Standard error of residual	3.786830				
Akaike information criterion	152.9958				
Bayesian information criterion	159.4750				

Additional information. (style: Figure info)

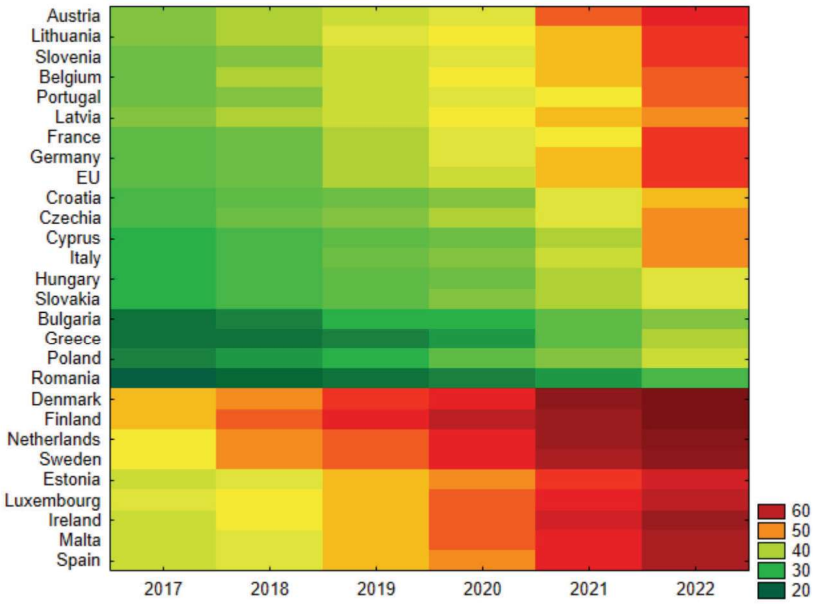
Source: Own preparation based on Digital Economy Society Index and Summary Innovation Index)

Scheme 1. Scoping the Digital Economy (the tiers of the Digital Economy)



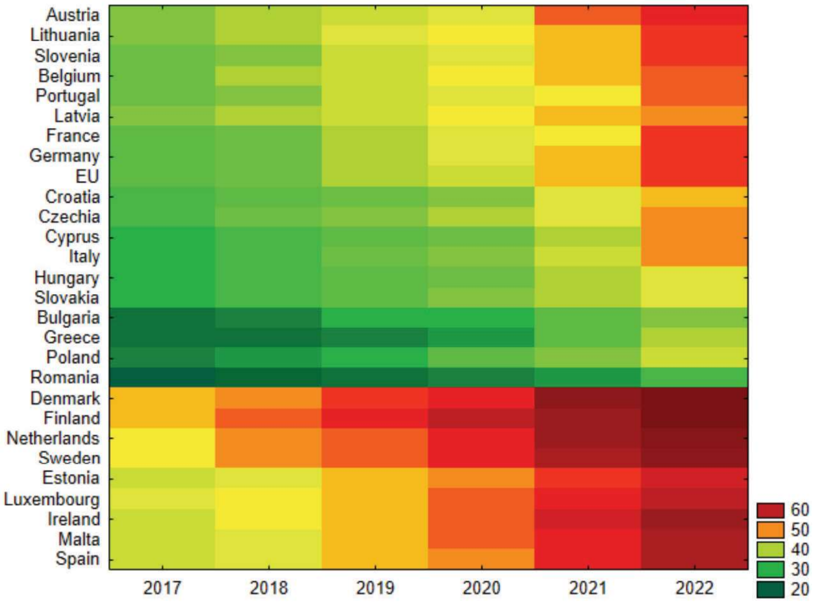
Source: Own preparation based on Bukht, R. &Heeks, R. (2017). Defining, Conceptualising and Measuring the Digital Economy (Working Paper No. 68). Manchester: Center for Development Informatics, Global Development Institute, SEED. https://doi.org/10.2139/ssrn.3431732.

Figure 1. Changes in Digital Economy and Society Index between 2017 and 2022



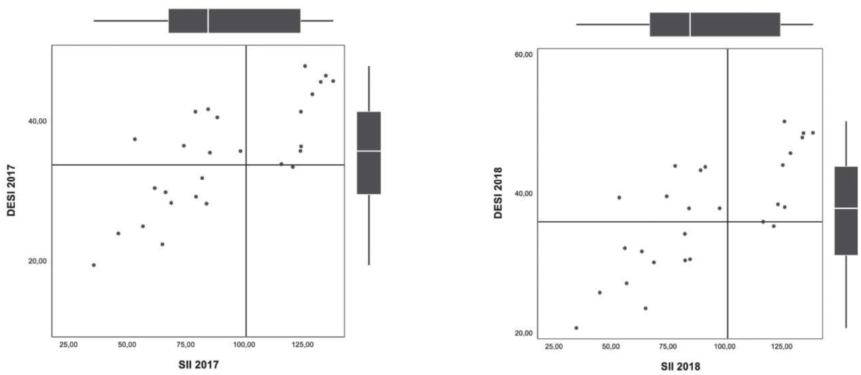
Source: own elaboration based on Digital Economy and Society Index.

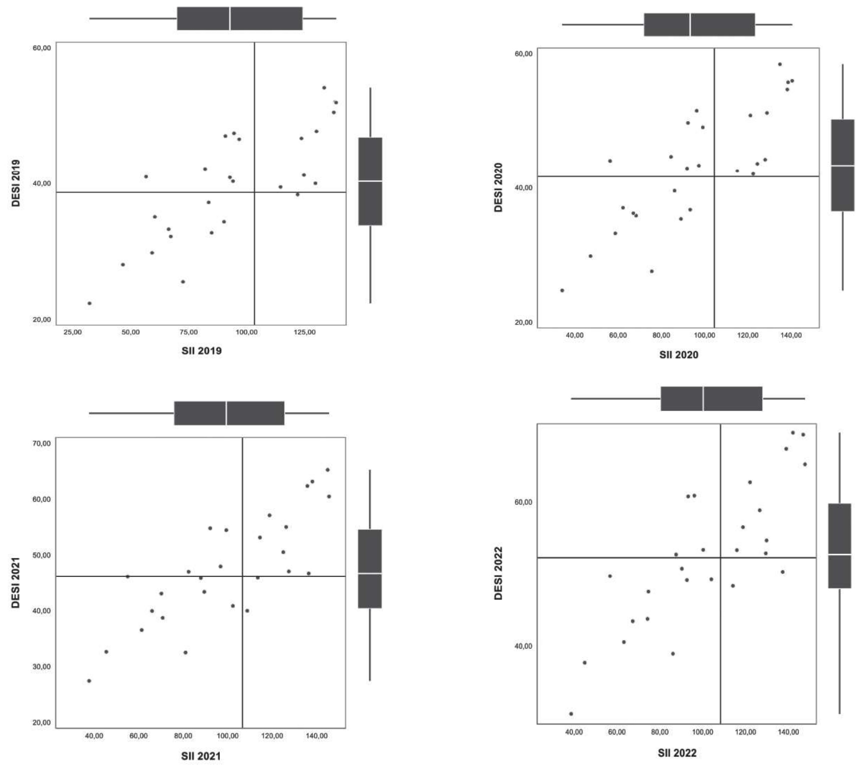
Figure 2. Changes in Summary Innovation Index between 2017 and 2022



Source: own elaboration based on European Union Scoreboard, figures prepared in Statistica.

Figure 3. The correlation scatter diagrams – SII vs DESI in the years 2017–2022





Source: own elaboration based on DESI and SII values, figures prepared in SPSS.