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Asymmetry and convergence in the development of digital technologies in the EU countries

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Keywords: *EU; digitalization; digital gap; digital technologies; convergence; digital strategy; competitiveness*

Abstract

Research background: Digitalization in the context of the COVID-19 pandemic has accelerated significantly across Europe, including in regions that are at the stage of catch-up development. However, as innovative technologies are intensively integrated into everyday life, the digital gap between the EU countries is increasing. The widening digital gap is becoming a serious threat to achieving the EU's sustainable development goals and building a sustainable European society.
Purpose of the article: The purpose of the article was to empirically substantiate the inclusiveness and convergence of the digital strategy in the EU countries.
Methods: Using the method of fuzzy sets, the level of asymmetry in access to transactional (e-commerce), information (cloud computing), operational (artificial intelligence) technologies

in the EU countries was assessed. The negative impact of the digital gap within the countries (the gap between small, medium, large companies) and the global digital gap (the gap between EU countries) on the competitiveness of countries was established, for which correlation analysis and the Granger causality test were used.
Findings & value added: The findings of this study contribute to the literature of digital transformation and digital gap of European countries. The impact of the digital gap in transactional, information, operational technologies on the competitiveness of countries is differentiated depending on the level of digitalization of the country. Cluster groups of countries are determined by the convergence of digitalization and ways to ensure long-term competitiveness. The directions for reducing the digital gap in the EU countries are substantiated by changing the priorities of spending on innovation and increasing productivity, diversifying the digital technologies used. The empirical results obtained can serve as a basis for improving the effectiveness of the digitalization policy in the EU countries in accordance with individual convergence goals. The main added value of the paper is related to the presented research procedure, which can be used in analyses of digital technologies development also for other countries. The results provide valuable insights into evaluating the digital technologies in European countries.

Introduction

The digitalization of society in modern conditions is an integral fundamental process of economic, socio-political transformation and cultural transformation around the world, due to the acceleration of demographic changes, the deterioration of climatic conditions (Nadoleanu *et al.*, 2022). Digital transformation has become the most effective way for enterprises to develop nowadays, and digitalization has become an important motive for shaping innovative economic models (Liu *et al.*, 2023). Digitalization involves rethinking the approach to business, social security, increasing efficiency by optimizing and automating business processes, as well as organizing the coordinated work of IT systems. The ongoing digital transformation forces companies to rethink business strategies, ways of doing business, business models and operations (Verhoef *et al.*, 2021; Plekhanov *et al.*, 2022).

Increasing competitiveness and productivity, improving communication and accelerating managerial decision-making based on technological innovations has been the backbone of the European Union (EU) development over the past seven decades (Tutak & Brodny, 2022). Digitalization improves people's lives, education, ensures economic growth and eco-protection, and increases the level of country competitiveness (Marti & Puertas, 2023). Many countries in the EU have been able to achieve an advanced level of digitalization of society and receive 20% more economic and social benefits than countries whose economies are at the entry level in the region (PwC, 2012). The need to accelerate the digitalization of all areas of socio-economic development has become especially acute during the spread of the COVID-19 pandemic. Many countries have developed special policies aimed at driving digital innovations to ensure competitiveness in the highly competitive post-COVID-19 society (Luo *et al*., 2023), and digital skills have formed the basis of modern management of the socio-economic system and the healthcare system (Marhraoui, 2023; Reddy *et al*., 2023, Ma *et al*., 2022).

Increasing demand for digitalization and its intensification has drawn more attention to the digital inequality both worldwide and in the EU countries. For example, Denmark and Spain provide the population with almost 100% high-speed Internet coverage (World Economic Forum, 2022). Whereas at the beginning of 2022, countries such as: Italy has 44% coverage, Cyprus has 41% and Greece has 21%; and they are characterized by the lowest level of coverage (World Economic Forum, 2022). In addition, the EU digital gap is characterized not only by the level of development of the country's economy, but also by population or regional affiliation. For example, in rural areas of Greece, high-speed Internet access is completely absent. In the Czech Republic, this figure is 7%, while in Finland it is slightly higher: 12% of rural houses (Eurostat, 2022a). Besides, the digital gap in EU countries caused by different technological developments requires changes in the approach to modern technologies, greater educational activity, and the launch of innovative digital businesses (Malkowska *et al*., 2021).

The ambitious strategic goal of the EU by 2030 is to achieve 100% connectivity of the continent through gigabit internet connectivity (European Commission, 2022). However, despite the fact that over the past 8 years, EU countries have reduced the gap in binary access to the Internet by 54%, most countries have not made significant strides in technological innovations (World Economic Forum, 2022). With the process of intensifying the digitalization of society in low-income countries, the cost of mobile broadband Internet is becoming increasingly expensive, but in developing EU countries, in relation to the average income of the population, Gigabit Internet is 18 times more expensive than in developing countries, and this represents a significant problem in implementing initiatives to increase access to digital technologies and aggravates the digital gap (Eurostat, 2022a).

Minimizing the digital gap between EU countries is becoming more and more urgent as critical aspects of everyday life such as education, financial services, healthcare, media, communications and more become increasingly dependent on access to digital technologies. Given the fact that the gap within the EU in digital skills development (digital technology use) (as of 2022, only 50% of the EU population had digital skills) is even greater compared to Internet access, not addressing the problem will aggravate inequalities in economic development, access to health services, education, etc., which will adversely affect the implementation of the EU goals in the Sustainable Development Agenda (Van Kessel *et al*., 2022). Digital transformation of the countries must ensure sustainability and benefits for society (Nosratabadi *et al*., 2023) as well as achieve integrated smart, sustainable and inclusive growth at the European level (Akande *et al*., 2019).

Analysing the digital transformation of the countries and the digital gap, various studies exist on current trends and challenges (Schradie, 2011; Skare & Riberio Soriano, 2021; Lythreatis *et al*., 2022). There are also numerous research papers that analyze efficiency and digital transformation of countries in different areas: economic, social, ecological or public governance (Akande *et al*., 2019; Nosratabadi *et al*., 2023; Carlsson & Rönnblom, 2022; Hung *et al*., 2023; Marti & Puertas, 2023).

However, the authors usually focus on the analysis of narrow issues by using selected variables and limited areas. Therefore, the research outcomes obtained by different scientists do not always allow for comparison. Taking into account the complexity of the digital development of the countries as well as the high significance of upgrading the digital policies of the countries according to the European Agenda, it is highly necessary to broaden the research approach both empirically and methodologically. The impact of the digital gap in transactional, information, and operational technologies on the competitiveness of countries and the effectiveness of the digitalization policy in the EU countries in accordance with individual convergence goals to ensure European competitiveness and achieve the sustainability of the European economy are essentially needs. Our research responds to this need, both in terms of the research framework and the approach used.

As part of our study, we made an attempt to compare the level and dynamics of the digital gap in terms of information technology modifications in the EU countries at the present stage of innovative development and achievement of sustainable development goals. Our research contributes on numerous aspects to the development of the conceptual framework of the digital gap. First, we emphasized the importance of a comprehensive study of the second level of the digital gap in today's environment, as the development of information skills provides opportunities for the use of various types of information technologies. Secondly, we came to the conclusion that not only does the digital gap still exist in the EU in terms of binary access to the Internet, but the gap in the types of use of information technologies is widening. Overcoming such digital gaps requires comprehensive and timely solutions.

The purpose of the article was to empirically substantiate the inclusiveness and convergence of the digital strategy in the EU countries. The exploration and insights of this paper primarily address the digital gap in transactional, informational, and operational technologies and substantiate the inclusiveness and convergence of the digital strategy in the EU countries, which is highly relevant to ensuring sustainable development. In order to achieve the goal of this study, analyses, syntheses of data regarding the literature on the digital gap have been explored. A comparative analysis of selected indicators of digital transformation in the 28 EU member countries based on the public Eurostat statistics has been conducted. For data analysis and estimation of the digital gap, a multi-method approach based on various methods was applied. Thus, the fuzzy set method was chosen as it allows for a balanced estimation of the level of digital indicators. Fibonacci rule was used to estimate the qualitative level of the digital gap. In addition, correlation analysis was used to assess the impact of digitalization and the digital gap on the competitiveness of the countries. Statistica 12 program has been applied to analyse data based on the methods mentioned. The findings provide an opportunity to identify a group of countries that have converged on digitalization and determine ways to ensure long-term competitiveness. In addition, the empirical results obtained can serve as a basis for improving the effectiveness of the digitalization policy in the EU countries in accordance with individual convergence goals.

The remainder of this paper is structured as follows: in the following section, a review of relevant literature will be conducted. In section 3, the research methodology and data sources will be presented. The following section will present the results and discussion. Subsequently, the most significant conclusions will be summarized and research limitations provided.

Literature review

Scientific studies of the digital gap are characterized by a fairly short period of observation. There is no solid, formed base of conceptual provisions and theories. The term "digital gap" itself appeared relatively recently at the end of the 20th century, which implied differences in access to the Internet among different segments of the population (Acılar *et al*., 2011; Guo & Wan, 2022; Liao *et al*., 2022; Civelek *et al*., 2023).

Investigation of digital transformation from a corporate perspective and determination of asymetry on the micro level are significant to provide relevant guidance for formulating digital related policies and ensuring integration of the digital economy and real economy (Sun *et al*., 2022a; 2022b).

With the development of digital technologies and the complexity of digital processes, the content of the digital gap has become more complex, and in more modern works, the digital gap already reflected three components:

- inequality of access to the Internet within a region, country, mainland, etc.;
- a gap in the development of digital skills, the expected possibility of introducing and using various digital technologies: transactional (electronic commerce), information (cloud computing, big data analysis, machine learning), operational (3D printing and robotics, Internet of things, artificial intelligence);
- awareness of the usefulness of using digital technologies (The World Bank Group, 2020).

The most researched aspect in academia is the first level of the digital gap, while the third level of the digital gap seems to be largely unexplored due to the lack of scientific development of the second level of the digital divide (Sánchez-Torres, 2019; Bickley *et al*., 2021).

Brunet-Thornton *et al.* (2019), Appiah-Otoo and Song (2021) argued that digitalization, depending on the level of digital skills and the type of technologies used, can have a twofold effect on innovation development: widen or narrow the gap, regardless of the regional level of research. In view of the fact that transactional technologies and mastering the skills of their use, they mainly involve the digitalization of the main functions of various types of payments, sales and marketing. Therefore, their introduction into business, the social environment creates a huge potential for achieving geographic solidity, convergence by overcoming market barriers for medium and small enterprises, etc. (Pliskin *et al*., 2006). SME's are more flexible and changeable with instant transactional technologies, but implementation of operational technologies requires high investment, and budget deficiencies slow down such development (Ulas, 2019). Conversely, according to Dondapati *et al.* (2022), Bonsón *et al.* (2021), such types of digital technologies as big data analytics or robotics, representing modifications of information and operational digital technologies contribute to an increase in the digital gap due to the capacity and high cost of implementation, the need to form a medium and high level of digital technologies for their implementation. This means that these types of information technologies, as they develop, can exacerbate the digital gap and cause the destruction of competitiveness at the level of a region, country, or cross-country inequality. Based on the forgoing:

H1: *The digital gap between small and large companies is more significant when using operational technologies than when using transactional technologies, and its impact on competitiveness is more destabilizing*.

Digital adoption dynamics in businesses in the EU differ by size of companies and type of technology, and large firms in the EU faster adopt big data in their businesses compared with medium and small companies (Skare & Riberio Soriano, 2021). Moreover, digitally developed economies lead the way in information technology, so country-level and firm-level research to explore the nature of the digital technology adoption mechanism is significant (Lythreatis *et al*., 2022; Skare & Riberio Soriano, 2021). Digital technologies spillover effects are higher in high- and middle-income to low-income countries and poor government policies, inadequate infrastructure contribute to the creation of specific challenges in each country (Marti & Puertas, 2023, Lythreatis *et al*., 2022). The competitiveness and digital development of enterprises are highly dependent on the external environment, including the national legislative framework (Luo *et al*., 2023). The destabilizing effect of the digital gap on competitiveness necessitates the simultaneous development of all types of digital technologies for small, medium and large companies. At the same time, different levels of economic development of the EU countries, different financial opportunities, and different levels of development of the legislative framework in the field of digital economy regulation cast doubt on the need for synchronization across countries. In this regard, hypotheses are formulated:

H2: *To ensure the competitiveness of countries, the priority should not be to ensure global inclusiveness and convergence of digital technologies between all EU countries, but to achieve convergence within the country.*

H3: *In order to ensure the competitiveness of the EU countries, the emphasis in the development of digital technologies and the elimination of the digital gap between small and large companies is shifting from the development of transactional technologies to information and operational ones as the digitalization of countries develops.*

The estimation of the digital transformation of the economy and society has been explored by numerous researchers. Most papers are based on the Digital economy and society index, Digital competitiveness index, Human development index or others indicators, which characterize economic growth. However, most studies are limited to one type of method, one area (for example society), or indicators.

For example, clustering method with the k-means algorithm was used by (Polozova *et al*., 2021) to group EU–28 countries and show the linkage between digital and human development as well as the linkage between digitalization and global competitiveness of the EU countries, based on Eurostat data. Such research was limited to a single method and area. Similarly, Marti and Puertas (2023), Malkowska *et al*. (2021), Nosratabadi *et al*., (2023) used the approach of grouping EU countries according to the similarities and differences in digital transformation. In addition, researchers used an advanced approach with the application of the multi-criteria decision-making method (TOPSIS) to rank the countries according to the level of digitalization and innovations (Marti & Puertas, 2023), as well as technological and economic development (Malkowska *et al*., 2021).

However, digital transformation processes in small and large enterprises are different (Ulas, 2019; Dondapati *et al*., 2022; Bonsón *et al*., 2021). At the same time, it is important to evaluate digital transformation by type of technology (Hallward-Driemeier *et al*., 2020), since each of them has its own development features, which should be the basis for the formation of a national digital strategy. This particular component is the peculiarity of our analysis, which distinguishes it from other research.

Against this backdrop, we propose to measure the digital transformation in European countries, considering both types of digital technologies and the volume of enterprises, based on a multistep approach. This enables not only cross-country comparisons, but also cross-enterprises and cross-digital technologies.

In particular, cluster analysis answers questions such as which cases are more similar to each other, while the fuzzy method can identify differences in configuration that represent sufficient conditions for an outcome (Greckhamer *et al*., 2018; Ordanini *et al*., 2014; Pappas & Woodside, 2021). The fuzzy set method is becoming more popular in a large part of studies: e-business and marketing (Pappas *et al*., 2016; Pappas, 2018; Woodside, 2017), strategy and organizational research (Fiss, 2011; Greckhamer *et al*., 2018), consumer psychology (Schmitt *et al*., 2017), etc. To identify the level of use of digital technologies (transactional, informational, and operational) by companies in EU countries and the digital gap — the level of asymmetry in access of small, medium and large companies to these technologies, we attempted to use the fuzzy set method. This is advisable since this method allows us to obtain a balanced assessment of the level of digitalization, avoiding a situation where high values of some indexes compensate for low values of others.

Research methods

The research methodology involved the use of the fuzzy set method (trapezoidal membership function) to identify the level of use of digital technologies (transactional, information, operational) by companies in the EU countries and the digital gap — the level of asymmetry in the access of small, medium and large companies to these technologies. The use of the fuzzy set method is due to the fact that it allows to get a balanced assessment of the level of digitalization, avoiding a situation where the high values of some indicators compensate for the low values of others. To assess the level of use of digital technologies, indicators were used (Table 1) for the period 2015–2021 for small, medium, large companies in EU–28 member countries and states that have EU candidate status (Eurostat, 2022a). To take into account the fact that digital transformation is distinguished on the volume of enterprise (Lythreatis *et al*., 2022; Skare & Riberio Soriano, 2021), it is reasonable to analyse indicators according to the group of small, medium and large companies. The category of small enterprises includes enterprises with 10–49 employees, medium enterprises with 50–249 employees, and large enterprises with 250 employees and more (Eurostat, 2022b). According to the methodology of Eurostat (2022a), the sample for the EU countries was formed by enterprises of all industries in the amount of about 151 thousand enterprises. Based on the approach, which focuses on three types of process technologies within Industry 4.0, the indicators have been selected for the analysis (Hallward-Driemeier *et al*., 2020).

Among the indicators of the use of transactional technologies, those that characterize the volume of e-commerce, the use of electronic accounts, which take into account the functionality of websites for automating e-commerce. The degree of use of information technologies is described by indicators of the share of enterprises that carry out cloud computing and analyze big data. The scale of the spread of operational technologies is described through indicators of the use of the Internet of Things, artificial intelligence, 3D printing, industrial and service robots by enterprises (The World Bank Group, 2020). Based on the values of the indicators (Table 1), the Cronbach's Alpha coefficient was calculated in the Statistica 12 program. The coefficient value was 0.79 for the group of transactional technologies, 0.84 for information technologies, and 0.86 for operational ones. The value of the coefficients is in the range of 0.7-0.9, which statistically confirms the consistency of the choice of indicators to characterize each type of digital technologies (Hair *et al*., 2017).

The range of digitalization indicators (Table 1) is divided into 3 levels according to the Fibonacci rule (Formula 1) and adjusted using the t-test for independent samples (Megits *et al*., 2020).

$$\begin{cases} D_1 = D_{min} + 0.38(D_{max} - D_{min}) \\ D_2 = D_{min} + 0.62(D_{max} - D_{min}) \end{cases} \quad (1)$$

where:

D	indicator of digitalization;
D_{min}	the minimum value of the digitalization indicator for a sample of countries;
D_{max}	the maximum value of the digitalization indicator for a sample of countries;
$[D_{min}; D_1]$	low-level range of digitalization indicators;
$(D_1; D_2]$	range of the average level of digitalization indicators;
$(D_2; D_{max}]$	high-level range of digitalization indicators.

As a result, the ranges of levels were formed, the differences in the values of the indicators between which are statistically significant according to the t-test at p=0.05. Values that were not included in these ranges formed intermediate levels.

The integral indicators of the development of digital technologies are determined separately for transactional (*TS, TM, TL*), information (*IS, IM, IL*), operational (*OS, OM, OL*) technologies in the context of small, medium and large enterprises according to the formulas (2)-(5) (Krawczak & Szkatuła, 2020).

$$\mu_1 = \begin{cases} 1, \ D_{imin} \leq D_i \leq D_{i1} \\ \dfrac{D_{i2} - D_i}{D_{i2} - D_{i1}}, \ D_{i1} < D_i < D_{i2} \\ 0, \ D_{i2} \leq D_i \leq D_{imax} \end{cases} \tag{2}$$

$$\mu_2 = \begin{cases} 0, \ D_{imin} \leq D_i \leq D_{i1} \\ \dfrac{D_i - D_{i1}}{D_{i2} - D_{i1}}, \ D_{i1} < D_i < D_{i2} \\ 1, \ D_{i2} \leq D_i \leq D_{i3} \\ \dfrac{D_{i4} - D_i}{D_{i4} - D_{i3}}, \ D_{i3} < D_i < D_{i4} \\ 0, \ D_{i4} \leq D_i \leq D_{imax} \end{cases} \tag{3}$$

$$\mu_3 = \begin{cases} 0, \ D_{imin} \leq D_i \leq D_{i3} \\ \dfrac{D_i - D_{i3}}{D_{i4} - D_{i3}}, \ D_{i3} < D_i < D_{i4} \\ 1, \ D_{i4} \leq D_i \leq D_{imax} \end{cases} \tag{4}$$

$$DI = \sum_{i=1}^{n} \mu_{1i} \times \lambda_{1i} + \mu_{2i} \times \lambda_{2i} + \mu_{3i} \times \lambda_{3i}, \tag{5}$$

where:

μ_1 the probability of referring the *i* indicator to a low level, μ_2 – to average level, μ_3 – 3 to high level;

D_i the indicator of digitalization;

D_{imin} the minimum value of the *i* indicator of digitalization in the sample of countries;

D_{imax} the maximum value of the *i* indicator of digitalization in the sample of countries;

D_{i1} - D_{i4} values of the digitalization indicator, adjusted using the t-criterion, which correspond to the low, medium and high levels of indicators;

DI the value of the integral indicator of digitalization (*TS, TM, TL, IS, IM, IL, OS, OM, OL*);
λ conditional variables that, depending on the level of the i-th indicator, take on the following values: λ_1=0 for a low level, λ_2=0.5 for an average level, λ_3=1 for a high level;
n the number of indicators on the basis of which the integral indicator is calculated

The digital gap is calculated separately for transactional (ΔT), information (ΔI), operational (ΔO) technologies for each country as an absolute difference in the values of the integral indicator of the development of certain technologies among large and small enterprises. The qualitative level of the digital gap (low, medium, high) is determined by the Fibonacci rule (formula 1).

The Global Digital Gap (*GDG*) for all EU countries and countries that have EU candidate status is calculated as the coefficient of variation of the integral indicator of the development of digital technologies (*TS, TM, TL, IS, IM, IL, OS, OM, OL*) for transactional, information, operational technologies.

Correlation analysis was used to assess the impact of digitalization and the digital gap on the competitiveness of the countries. Correlation coefficients are calculated for the period 2015–2021:

- between the integral indicator of the use of transactional technologies and the indicator of competitiveness for small enterprises ($r_{TS\text{-}C}$), medium-sized enterprises ($r_{TM\text{-}C}$), and large enterprises ($r_{TL\text{-}C}$);
- between the integral indicator of the use of information technology and the indicator of competitiveness for small enterprises ($r_{IS\text{-}C}$), medium-sized ($r_{IM\text{-}C}$), and large enterprises ($r_{IL\text{-}C}$);
- between the integral indicator of the use of operating technologies and the indicator of competitiveness for small enterprises ($r_{OS\text{-}C}$), medium-sized ($r_{OM\text{-}C}$), and large enterprises ($r_{OL\text{-}C}$);
- between the transactional gap and the indicator of competitiveness ($r_{\Delta T\text{-}C}$);
- between the information gap and the indicator of competitiveness ($r_{\Delta I\text{-}C}$);
- between the operational gap and the indicator of competitiveness ($r_{\Delta O\text{-}C}$);
- between the global digital gap and the indicator of competitiveness ($r_{GDG\text{-}C}$).

The direction of cause-effect relationships between the studied indicators was determined using the Granger test in the EViews 10 program (Table 2). The use of the Granger test and correlation analysis became possible due to the normal distribution of the estimated indicators and their stationarity, proven by the extended Dickey-Fuller test (Rajbhandari & Zhang, 2021).

The probability of a lack of communication does not exceed 5%, which indicates the impact of digitalization and digital gap indicators on the competitiveness of EU countries and countries that have EU candidate status. In order to determine the priority areas for digitalization of the EU countries and countries that have EU candidate status, to ensure their competitiveness, cluster analysis was employed, using the hierarchical clustering method (to determine the number of clusters) and *k*-means to determine cluster members and check the statistical significance of the results).

For clustering, digitalization indicators (*TS, TM, TL, IS, IM, IL, OS, OM, OL*) for EU countries and correlation coefficients ($r_{TS\text{-}C}$, $r_{TM\text{-}C}$, $r_{TL\text{-}C}$, $r_{IS\text{-}C}$, $r_{IM\text{-}C}$, $r_{IL\text{-}C}$, $r_{OS\text{-}C}$, $r_{OM\text{-}C}$, $r_{OL\text{-}C}$, $r_{\Delta T\text{-}C}$, $r_{\Delta I\text{-}C}$, $r_{\Delta O\text{-}C}$, $r_{GDG\text{-}C}$) for the EU countries for the period 2015–2021, the Statistica 12 program was used.

Results and discussion

The upward dynamics of the digitalization indicators of the EU countries for the period 2015–2021 indicates an increase in the degree of use of transactional, information, operational digital technologies. Despite this, for all countries, the actual values of the indicators are significantly lower than the potential ones. The use of the fuzzy set method made it possible to identify the following levels of digitalization indicators (Table 3).

Based on the obtained ranges of indicators (Table 3), using formulas (2)-(5), the levels of use of digital technologies in the EU countries were determined (Figure 1).

Among the EU–28 countries and countries that have the EU candidate status, Denmark, the Netherlands, Sweden, Norway, Germany, Iceland, the United Kingdom have higher rates of use of digital technologies. For these countries, the use of transactional, information and operational technologies by large enterprises is predominantly at a high level. Despite the highest levels of digitalization, the use of technology by SMEs is low to medium as a result of the high cost of technology and limited access to finance for SMEs. The income from e-commerce for small enterprises does not exceed 14.7% of the turnover of enterprises, for medium-sized enterprises — does not exceed 23.1%. On average, 4.2% of small enterprises, 8.7% of medium enterprises, and 20.9% of large enterprises use internal analysis of big data using machine learning (Eurostat, 2022a).

For Czechia, Estonia, Spain, France, Italy, Latvia, Luxembourg, Austria, Portugal, Slovenia, Slovakia, Cyprus, Lithuania, Ireland, Malta, Finland, Belgium, the use of digital technologies is less significant, except for the use of operational technologies by small businesses. The use of these technologies is low, but higher than in other EU countries.

The lowest digital adoption rates for all enterprises (small, medium and large) are for the following countries: Bulgaria, Greece, Hungary, Romania, Montenegro, North Macedonia, Serbia, Bosnia and Herzegovina, Croatia, Poland. Regardless of the scale of enterprises, the use of technology is characterized by low intensity. The income from e-commerce for small enterprises on average for these countries is 8.1% of the turnover of enterprises, for medium-sized enterprises — 9.3%, for large enterprises — 12.1%. On average, 1.3% of small enterprises, 2.4% of medium enterprises, and 3.6% of large enterprises use internal analysis of big data using machine learning (Eurostat, 2022a).

The statistical significance of cluster analysis is evidenced by the excess of intergroup variance (between SS) over intragroup variance (within SS) for all indicators of clustering, the statistical significance of the F-test (Cunningham *et al*., 2013) for all indicators (Table 4).

The calculated indicators of the use of transactional, information and operational technologies and the conducted cluster analysis indicate:

1. trends in the development of digitalization in the EU countries and countries that have EU candidate status;
2. the presence of a digital gap in all EU countries and countries that have EU candidate status: the level of use of digital technologies increases with the increase in the size of enterprises;
3. the same countries have higher rates of digitalization in transactional, information and operational technologies for small, medium and large enterprises. This indicates that the problems of developing digital technologies in countries with a low level of technological development are of a systemic nature: a lower level of economic development and, as a result, a lack of financial resources for technology development, a less developed legislative framework.

The calculated value of the digital gap for the EU countries and countries that have EU candidate status for 2021 is shown in Table 5.

Countries with less developed digital technologies have a low level of digital gap — Bulgaria, Romania, Montenegro, North Macedonia, Serbia, Bosnia and Herzegovina. Higher digital gap has countries with the highest rates of digital use (Denmark, Netherlands, Sweden, Norway, Iceland). In terms of technology, there is a more significant digital gap in the use of operational technologies, and these differences are confirmed by a t-test (empirical test value of 3.05 is statistically significant at p=0.05) (Cunningham *et al*., 2013). For other technologies, the digital gap is statistically significant at p=0.10. This confirms the hypothesis **H1** that the digital gap between small and large companies is more significant when using operational technologies comparing with transactional technologies. The use of operational technologies requires a significant financial basis and the qualifications of workers that large companies can provide. At the same time, these technologies also have a significant return, increasing labor productivity, profitability of enterprises, and financial stability. Therefore, enterprises that have the necessary basis for the development of technologies tend to expand the scale of the use of operational technologies. The introduction of transactional technologies requires fewer resources, they are more accessible, so the gap in the use of technologies by small and large companies is less significant.

To test the second part of the H1 hypothesis that the impact of the digital gap between small and large companies when using operational technologies on the competitiveness of companies is more destabilizing, paired correlation coefficients were calculated.

Correlation coefficients indicate that the impact of the digital gap in the use of transactional, information, operational technologies on the competitiveness of countries is negative and significant at p=0.10. But analysis across the entire sample of EU countries and countries that have EU candidate status did not confirm the H1 hypothesis that the impact of the gap in the use of operational technologies on competitiveness is more destabilizing than the impact of transactional technologies. The power of the digital gap varies by country.

The impact of the global digital gap on the competitiveness of the EU countries for a number of countries (Denmark, the Netherlands, Sweden, Norway, Iceland) is not statistically significant. The values of pairwise correlation coefficients are not statistically significant at p=0.10. Countries that are more resilient to the global digital gap and have higher rates of digitalization. For other countries, the correlation coefficients between the global digital gap and competitiveness are statistically significant at p=0.10.

The calculated correlation coefficients confirm the **H2** hypothesis that in order to ensure the competitiveness of countries, the priority should not be to ensure global inclusiveness and convergence of digital technologies between all EU countries, but to achieve convergence within the country.

In the paper (Gavkalova *et al*., 2017), the authors proved that the cumulative impact of policy leverages and instruments create conditions for the environment in which the government must take measures in order to ensure effective implementation of its regulatory policy based on the integrated index of socio-economic development. Obviously, effective digital government policy should base on such leverages, directed on leveling the digital gap within the country. Directions and leverages of government regulation should be differentiated not only according to each country, but also according to the type of digital technologies.

To determine the priority directions of the digitalization strategy of the EU countries and countries that have EU candidate status, countries were clustered according to the correlation indicators between the indicators of digitalization, digital gap and competitiveness (Table 6).

During clustering, no statistically significant clustering ability of the correlation coefficients between the integral indicators of the development of information and operational technologies among small enterprises was found. At the same time, the correlation coefficients between the indicators of the digital gap and competitiveness ($r_{\Delta T\text{-}C}$, $r_{\Delta I\text{-}C}$, $r_{\Delta O\text{-}C}$) are statistically significant and have a statistically significant clustering ability. This means that the level of digitalization of small enterprises affects the competitiveness of countries, then the correlation coefficients do not have a significant clustering ability due to the low level of use of information and operational technologies by these enterprises.

Based on the results of clustering, 3 clusters of countries were identified that correspond to digitalization strategies (Figure 2).

Cluster 1 was formed by Bulgaria, Greece, Hungary, Romania, Montenegro, North Macedonia, Serbia, Bosnia and Herzegovina, Croatia, Poland, Slovakia, Latvia, Italy, Lithuania, Portugal, Cyprus, Czechia, Slovenia. These are the countries with the lowest rates of digitalization. For them, there are higher correlation coefficients between the integral indicator of the use of transactional technologies and competitiveness, and the highest modulo correlation coefficients between the digital divide indicator for transactional technologies and competitiveness. Therefore, the priority digitalization strategy for these countries is the strategy for the development of transactional digital technologies.

Cluster 2 was formed by Germany, Iceland, the United Kingdom, Estonia, Spain, France, Luxembourg, Austria, Ireland, Malta, Finland, Belgium. For these countries, the development of information technologies is a priority in the formation of a digitalization strategy.

Countries with the highest indicators of digitalization (Denmark, the Netherlands, Sweden, Norway) formed Cluster 3. For these countries, the strategy for developing operational digital technologies is a priority.

The obtained results confirm the **H3** hypothesis: in order to ensure the competitiveness of the EU countries, the emphasis in the development of digital technologies and the elimination of the digital gap between small and large companies is shifting from the development of transactional technologies to information and operational ones as the digitalization of countries develops.

The process of digitalization brought about significant changes in the economy, known as the modern industrial revolution (Adamek & Solarz, 2023), and which is based on digital innovations. This idea is further supported by the finding that the development of digitalization in the EU countries, which is important in the era of the digital economy and corresponds to the digital strategy of the EU.

Due to the complexity of the digital transformation process, it is difficult to estimate it especially in relation to the challenges taking place in the economy and society. It is worth mentioning the research conducted by Malkowska *et al.* (2021), which focused on evaluation of the impact of the digital transformation of EU countries based on the digitalization of society and economy. The main reasons for differences in the development of countries are digital skills and technological development, which lead to the digital gap. Other empirical studies have demonstrated the differences in digital skills in the EU countries (Marhraoui, 2023; Reddy *et al*., 2023; Ma *et al*., 2022), which is a significant factor in ensuring the sustainability of the societies.

Digital transformations in small and large enterprises have their own features (Ulas, 2019; Dondapati *et al*., 2022; Bonsón *et al*., 2021) and should be differentiated in accordance with the type of digital technologies (Hallward-Driemeier *et al*., 2020). Our findings highlight that the level of digital technology increases with the size of the enterprise. This finding may be explained by the idea that the implementation of digital innovations requires high investments, and small enterprises have limited financial resources.

Regarding the competitiveness of the economy, digital innovations are a driving force for each country as well as a key base for the well-being of people and economic development (Aytekin *et al*., 2022). The European Union, competing with other world economies, is creating the frameworks of digital policy in order to implement digital transformation in all areas of socio-economic life (Kučera & Fiľa, 2022) and ensure the competitiveness of the EU countries. We obtained evidence that to ensure the competitiveness of countries, the priority should not be to ensure global inclusiveness and convergence of digital technologies between all EU countries, but to achieve convergence within the country. In our research, cluster groups of countries are determined by the convergence of digitalization and our findings highlight ways to ensure long-term competitiveness according to a corresponding digital strategy. It will also be relevant for decision-makers to implement national digital policy and ensure the competitiveness of the economy.

Conclusions

Based on the empirical study, we have come to the following outcomes. To ensure the competitiveness of countries, the priority should not be to ensure global inclusiveness and convergence of digital technologies between all EU countries, but to achieve convergence within the country.

To ensure the competitiveness of the EU countries, the emphasis in the development of digital technologies and the elimination of the digital gap between small and large companies is shifting from the development of transactional technologies to information and operational ones as the digitalization of countries develops. For countries with the lowest digitalization rates (Bulgaria, Greece, Hungary, Romania, Montenegro, North Macedonia, Serbia, Bosnia and Herzegovina, Croatia, Poland, Slovakia, Latvia, Italy, Lithuania, Portugal, Cyprus, Czechia, Slovenia), competitiveness is possible by developing transactional digital technologies and minimizing the digital divide between small, medium and large companies.

For Germany, Iceland, the United Kingdom, Estonia, Spain, France, Luxembourg, Austria, Ireland, Malta, Finland, Belgium, the development and ensuring the inclusiveness of information technology is a condition for increasing competitiveness.

The growth of the competitiveness of countries with the highest indicators of digitalization (Denmark, the Netherlands, Sweden, Norway) is possible through the implementation of a development strategy and ensuring the inclusiveness of operational digital technologies.

Our study is not free of some limitations. The research was carried out according to the digitalization data of the EU countries, which limits the implementation of the results in the practice of studying the digital gap in other countries or regions of the world. In addition, in view of the fundamental nature of scientific issues, we have studied only the digital gap of the second level: the development of scientific competencies in the aspect of the use of digital technologies without taking into account the impact on the first and third levels of the digital gap. The results obtained will form the basis of an empirical study of these issues in our further research.

To conclude, this paper contributes to research on digital transformation in many ways. Firstly, the study covers a broad research perspective with three aspects: cross-enterprises and cross-digital technologies, based on the author's compiled set of indicators. Secondly, it has referred to the selected indicators reflecting the types of digital technologies and their usage by small, medium and large enterprises. Thirdly, for the purposes of data analysis, based on Eurostat data, both cluster analysis and fuzzy set method were applied.

Future studies can address the research question of how companies can accelerate digital transformation in the context of digital technologies usage. There is also an opportunity for more comparative research, either to seek validation for the proposed indicators or to provide an advanced explanation of research results. Further studies can also focus on the government's leverages and regulations to drive digitalization of business in accordance with the type of digital technology usage and how to implement an effective European Digital Decade policy as well as the sustainability of the countries. Given that this study includes only EU countries and states that have EU candidate status, future studies could also focus on expanding the geographical trajectory as well as how the current situation has changed in the context of global challenges. The findings of this study can also be relevant to practice, as they provide a framework for policymakers to design regulations on how to increase the effectiveness of digital transformation within the country and ensure the competitiveness of national economies.

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Annex

Table 1. Indicators of the use of digital technologies by small, medium, large companies in the EU–28 countries and countries that have the EU candidate status

Indicators	Symbol of indicators
Indicators of transactional technologies usage	
Turnover of enterprises from e-commerce sales, % of turnover	ECS
Turnover of enterprises with online sales >1% of total turnover, % of turnover	OS
Enterprises whose website provides online ordering or reservations, % of registered enterprises	ORD
Enterprises sending and/or receiving e-invoices suitable for automated processing, % of registered companies	INV
Indicators of information technology usage	
Enterprises implementing cloud computing, % of registered enterprises	CL
Enterprises engaged in big data analysis, % of registered enterprises	DAT
Enterprises engaged in internal analysis of big data using machine learning, % of registered enterprises	MAC
Indicators of operational technology usage	
Enterprises used by the Internet of Things, % of registered enterprises	IOT
Enterprises using artificial intelligence technologies, % of registered enterprises	AI
Enterprises used by 3D printing, % of registered enterprises	PR
Enterprises that use industrial or service robots, % of registered enterprises	ROB

Table 2. Cause-effect relationships between indicators of digitalization, digital gap and competitiveness in EU–28 countries and countries that have status of candidate

Casual relationships	Probability of non-existence relationships	Casual relationships	Probability of non-existence relationships
TS → C	0.03	OM → C	0.03
TM → C	0.00	OL → C	0.01
TL → C	0.01	ΔT → C	0.01
IS → C	0.03	ΔI → C	0.02
IM → C	0.00	ΔO → C	0.00
IL → C	0.00	GDG → C	0.04
OS → C	0.00		

Table 3. Levels of digital performance indicators in EU-28 countries and countries that have EU candidatures

Indicator*	Range of values		
	Low level	Average level	High level
ECS	≤ 19.8	[22.2; 33.6]	≥ 36.2
OS	≤ 15.4	[17.1; 26.1]	≥ 27.7
ORD	≤ 24.7	[26.2; 36.8]	≥ 38.6
INV	≤ 39.5	[41.7; 61.8]	≥ 62.6
CL	≤ 35.4	[36.8; 59.0]	≥ 59.5
DAT	≤ 20.6	[21.5; 34.1]	≥ 35.1
MAC	≤ 8.9	[9.1; 14.2]	≥ 14.8
IOT	≤ 27.1	[27.7; 44.2]	≥ 44.8
AI	≤ 24.6	[25.8; 40.1]	≥ 41.4
PR	≤ 9.3	[9.8; 15.1]	≥ 15.9
ROB	≤ 16.1	[16.8; 26.0]	≥ 26.9

Note: * Symbols of indicators correspond to Table 1.

Table 4. Indicators of statistical significance of clustering of EU–28 countries and countries that have EU candidate status, by level of use of digital technologies

Indicator	Between SS	Within SS	F	Indicator	Between SS	Within SS	F
TS	0.2784	0.1354	7.5394***	IL	2.4132	0.7723	48.4303***
TM	0.5522	0.4858	17.6162***	OS	0.1751	0.0170	3.5087**
TL	1.1589	0.6609	27.1785***	OM	0.4596	0.1712	5.7742***
IS	0.4716	0.2927	24.9732***	OL	1.8891	0.9734	30.0812***
IM	1.0779	0.6132	27.2458***				

Note: ** - indicators statistically significant at p=0.05, *** - indicators statistically significant at p=0.01.

Table 5. Digital Gap Indicator among EU–28 and countries that have EU candidate status, 2021

Country	Indicator of Digital gap		
	Transactional technologies (ΔT)	Information technologies (ΔI)	Operational technologies (ΔO)
Belgium	0.83	0.50	0.93
Bulgaria	0.17	0.00	0.00
Czechia	0.33	0.60	0.63
Denmark	0.67	0.63	1.00
Germany	0.58	0.28	0.63
Estonia	0.33	0.63	0.25
Ireland	0.67	0.53	0.50
Greece	0.50	0.13	0.13
Spain	0.83	0.63	0.58
France	0.83	0.50	0.63
Croatia	0.37	0.50	0.38
Italy	0.50	0.25	0.50
Cyprus	0.33	0.25	0.00

Table 5. Continued

Country	Indicator of Digital gap		
	Transactional technologies (ΔT)	Information technologies (ΔI)	Operational technologies (ΔO)
Latvia	0.60	0.35	0.38
Lithuania	0.33	0.35	0.40
Luxembourg	1.00	0.25	0.63
Hungary	0.33	0.25	0.50
Malta	0.50	0.50	0.63
Netherlands	0.50	0.48	0.55
Austria	0.57	0.40	0.63
Poland	0.50	0.25	0.75
Portugal	0.67	0.25	0.70
Romania	0.00	0.13	0.00
Slovenia	0.33	0.50	0.63
Slovakia	0.33	0.35	0.75
Finland	0.67	0.38	0.88
Sweden	0.67	0.55	0.83
Iceland	0.67	0.50	0.67
Norway	0.67	0.38	0.75
United Kingdom	0.33	0.60	0.63
Montenegro	0.17	0.10	0.25
North Macedonia	0.33	0.00	0.25
Serbia	0.17	0.13	0.23
Bosnia and Herzegovina	0.00	0.13	0.13
	- low level of digital gap;	*- average level of digital gap;*	*- high level of digital gap*

Table 6. Average values of clustering indicators of EU countries and countries that have EU candidate status, by digitalization strategies

Strategy	Average values of correlation coefficients									
	$r_{TS\text{-}C}$***	$r_{TM\text{-}C}$***	$r_{TL\text{-}C}$***	$r_{IM\text{-}C}$**	$r_{IL\text{-}C}$***	$r_{OM\text{-}C}$**	$r_{OL\text{-}C}$***	$r_{\Delta T\text{-}C}$***	$r_{\Delta I\text{-}C}$***	$r_{\Delta O\text{-}C}$**
Development of transactional digital technologies	0.73	0.81	0.88	0.60	0.63	0.49	0.61	-0.82	-0.72	-0.68
Development of information digital technologies	0.55	0.58	0.63	0.70	0.82	0.52	0.66	-0.72	-0.84	-0.74
Development of operational digital technologies	0.48	0.50	0.53	0.65	0.74	0.58	0.74	-0.64	-0.66	-0.78

Notes: $r_{TS\text{-}C}$, $r_{TM\text{-}C}$, $r_{TL\text{-}C}$ correlation coefficients between the integral indicator of the use of transactional technologies and the indicator of competitiveness for small, medium, large enterprises, respectively; $r_{IM\text{-}C}$, $r_{IL\text{-}C}$ - correlation coefficients between the integral indicator of the use of information technology and the indicator of competitiveness for medium and large enterprises, respectively; $r_{OM\text{-}C}$, $r_{OL\text{-}C}$ - correlation coefficients between the integral indicator of the use of operating technologies and the indicator of competitiveness for medium and large enterprises, respectively; $r_{\Delta T\text{-}C}$ - correlation coefficient between transaction gap and competitiveness indicator; $r_{\Delta I\text{-}C}$ - correlation coefficient between the information gap and the indicator of competitiveness; $r_{\Delta O\text{-}C}$ - correlation coefficient between operating gap and competitiveness indicator; ** - indicators, the clustering ability of which is statistically significant when p=0.05; *** - indicators, the clustering ability of which is statistically significant when p=0.01

Figure 1. Level of digitalization in the EU-28 countries and countries that have the EU candidate status, 2021

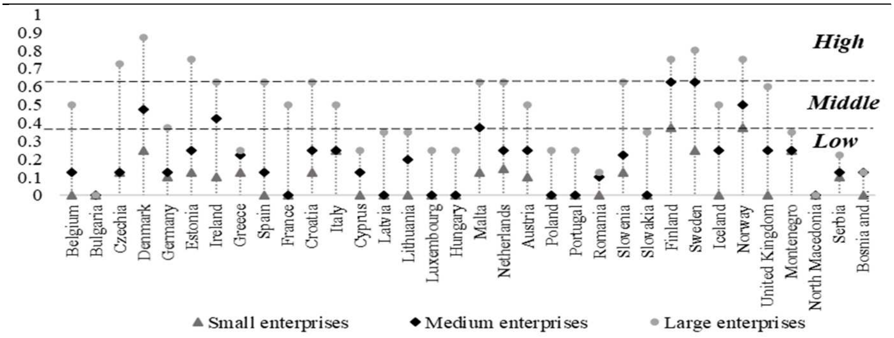
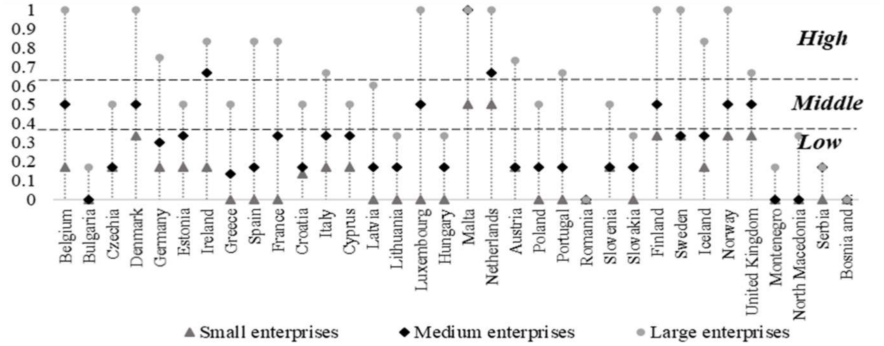


Figure 1. Continued

The level of transactional technologies usage



Level of information technology use

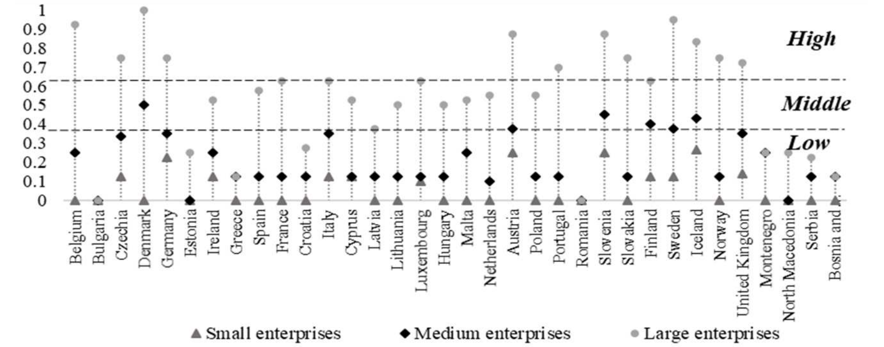
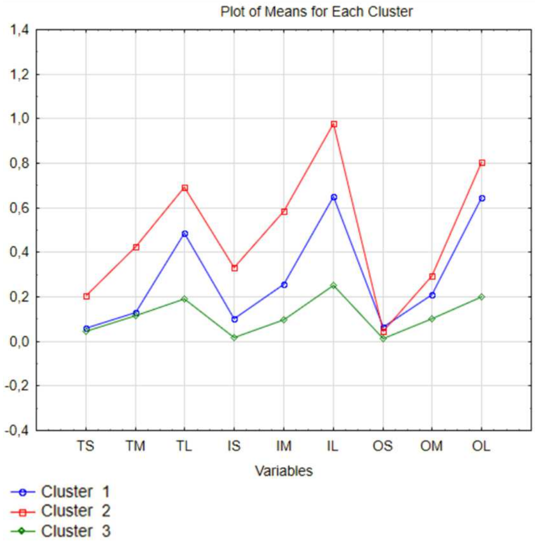


Figure 1. Continued

Level of operating technologies use



Cluster 1. Countries with a relatively high level of operational technologies use in small enterprises. Czechia, Estonia, Spain, France, Italy, Latvia, Luxembourg, Austria, Portugal, Slovenia, Slovakia, Cyprus, Lithuania, Ireland, Malta, Finland, Belgium.
Cluster 2. Countries with the highest rates of digitalization development regardless of the size of enterprises. Denmark, Netherlands, Sweden, Norway, Germany, Iceland, United Kingdom.
Cluster 3. Countries with a low level of development of digital technologies. Bulgaria, Greece, Hungary, Romania, Montenegro, North Macedonia, Serbia, Bosnia and Herzegovina, Croatia, Poland

Clusters of countries by level of use of digital technologies

TS - an integral indicator of the development of transactional technologies for small businesses; TM - an integral indicator of the development of transactional technologies for medium-sized enterprises; TL - an integral indicator of the development of transactional technologies for large enterprises; IS - an integral indicator of the development of information technologies for small businesses; IM - an integral indicator of the development of information technologies for medium-sized enterprises; IL - an integral indicator of the development of information technologies for large enterprises; OS - an integral indicator of the development of operational technologies for small businesses; OM - an integral indicator of the development of operational technologies for medium-sized enterprises;OL - an integral indicator of the development of operational technologies for large enterprises

Figure 2. Digitalization strategies of EU-28 countries and countries that have EU candidate status