The Integration of Digital Technologies in the European Union based on the DESI Index

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Abstract

Since the 2000s, the European Commission has been paying particular attention to the digital development of the European economy and society. Since 2014, the Digital Economy and Society Index (DESI) has been one of the key tools for monitoring and measuring. In 2021, the DESI index's core indicators were aligned with the objectives of the 2030 Digital Agenda, which has four dimensions: human capital, connectivity, integration of digital technology, and digital public services. We sought to determine whether convergence between the Member States could be detected using the third dimension of DESI's annual database. The σ-convergence analysis was used to estimate the reduction over time of the differences in digital technology integration between the Member States, while the β-convergence analysis was used to estimate the rate of catching up with the initial level of development. The σ- and β-convergence were not confirmed. We examined the individual indicators (11) of the integration of digital technology to identify critical areas that need to be addressed in the future to ensure that digital inclusion is as widespread as possible. Our analysis focused on the Member States that joined the EU during the Eastern European enlargements. The performance of all individual indicators is typically below the EU average, and, as the β-convergence analysis shows, the average catching-up rate is not encouraging.

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Introduction

The knowledge-based economy as a basis for human resource development and the continuously evolving research and development (R&D) in information and communication technologies are highly important for the European Union and are closely linked to its competitiveness (Bassanini et al., 2000). It is necessary to promote and amplify micro, small, and medium enterprises (MSMEs) to increase their growth and develop them as strong, resilient, efficient, and independent contributors to the national economy (Tumiwa et al., 2021).

The conscious development of all these at the EU level started with the Lisbon Strategy in 2000, followed by the EU 2020 Strategy in 2010. These strategies aim at the digital development of Europe, and the instrument is the Digital Agenda for Europe. To measure and monitor progress, the European Commission (EC) has created the Digital Economy and Society Index (DESI), which has been published annually since 2014 (Banhidi et al., 2019, Bánhidi et al., 2020).

The DESI was last significantly restructured and methodologically updated in 2021. In the same year, the European Parliament adopted the Digital Agenda 2030: A European way to achieve the Digital Decade, and the European Commission proposed the Path to the Digital Decade, a programme to contribute to the digital conversion of the European economy and society (European Commission, 2021a).

The DESI index currently ranks the EU Member States and monitors their progress based on four main and 33 individual indicators. The four main areas include:

- desi_1 Digital skills and competencies of human capital;
- desi_2 Internet coverage and quality of access;
- desi_3 Digital technologies in the enterprise;
- desi_4 The penetration of digital public services.

A previous study sought to determine whether convergence between the Member States could be detected using the DESI's annual databases (Kovacs et al., 2022). Using σ- and β-convergence tests, we found that convergence exists between the EU27 Member States for the DESI overall index, i.e., convergence can be statistically demonstrated. However, one may ask whether convergence can be demonstrated separately for the main indicators (desi_1, desi_2, desi_3, desi_4).

This study focuses on dimension 3 of the DESI index, which measures the degree of digital technology integration in the EU Member States. The main indicator desi_3 includes tree sub-dimensions and 11 individual indicators (Table 1):

Table 1
Structure of the Desi_3 (Digital Technologies in the Enterprise) Main Indicator

desi_3 subdimensions	Individual indicators
Digital intensity (desi_3a)	SMEs with at least a basic level of digital intensity
	Electronic information sharing
	Social media
Digital technologies for businesses (desi_3b)	Big data
	Cloud
	AI
	ICT for environmental sustainability
	e-Invoices
e-Commerce (desi_3c)	SMEs selling online
	e-Commerce turnover
	Selling online crossborder

Source: Authors' editing based on (European Commission, 2021a)

The degree of digital technology integration ranking is given by the weighted value of the desi_3 subdimensions 15-70-15%, i.e., desi_3a x 0.15 + desi_3b x 0.75 + desi_3c x 0.15.

The convergence of the development of the Member States that joined the European Union (EU) during the 2004, 2007, and 2013 enlargements to Eastern Europe and the old EU Member States is a priority, and convergence calculations are used to monitor the degree of cohesion in several areas. In this paper, we focus on two types of convergence. The first is the σ-convergence or relative standard deviation, the average relative deviation of the DESI index values from the mean, expressed as a percentage. If the dispersion of the development levels decreases over time, we speak of σ-convergence. Another well-known convergence indicator is β-convergence (Barro and Sala-i-Martin, 1992, Barro et al., 1991). This growth indicator is based on the neoclassical growth theories of Ramsey (1928), Solow (1956), and Koopmans (1963). The Solow-based and, from the 1980s onwards, endogenous growth theories argued that national economic policies and country-specific characteristics are crucial determinants of a country's catching-up performance. Foreign capital inflows accelerate growth, leading over time to narrowing the gap between developed and less developed catching-up countries.

The digital development of companies is also a priority area, as it is a key determinant of R&D and economic growth in a given region (Feldman, 1993, Mendez, 1998). As early as 1934, Schumpeter argued that technological change would be the determining factor. Companies unable to adapt to these technological innovations would be driven out of the market and thus out of competition (Schumpeter, 1934). According to Porter, a company's competitive advantage comes from how it organises and carries out its various activities. Nevertheless, to gain a competitive advantage, it must provide a service of similar value to its competitors but more efficiently or with a value differentiation that differentiates its product or service (Porter, 1985, Porter, 1998). The differentiation suggests that the appropriate integration and development of digital technology at the enterprise level can contribute to more efficient operations and, thus, to increased competitiveness. The collaborative economy is a distinct group of digital (platform) based businesses. The businesses that fall into this category are the market operators, providing instant access to products/services through their online platforms (Kovacs et al., 2021). The spread of the collaborative economy is facilitated by measures that support the integration of digital technologies, as each of the individual indicators listed in *Table 1* is also a potential component of the collaborative economy.

Industrial revitalization 4.0 requires preparing human resource skills to face changes in the labour market. Reducing the low-skilled and standard workforce is a real threat, especially in the manufacturing industry. However, the need for new skills and types of work will also become evident in the future, and more jobs will likely arise than jobs lost. Higher education must be able to adapt learning techniques and topics to meet the demands of technical competence, professional/methodological competence, social competence, and personal competence needed in the future (Zuegeh et al., 2021).

In this study, we analyse the DESI_3 index of the EU Member States between 2016 and 2021 to see if there is convergence in integrating digital technologies in enterprises across the Member States. No other authors have addressed this problem, and no forecasts or data have been published.

Our null hypothesis on desi_3 convergence is formulated as follows:

H_0: We assumed no convergence between the Member States based on the change in the desi_3 core indicator in 2016-2021.

Methodology

The σ-convergence refers to narrowing the gap between the Member States over time, while the β-convergence focuses on finding a possible catching-up process.

The σ-convergence (relative standard deviation or coefficient of variation) is a coefficient of variation that allows comparing manifolds or samples with different averages and characteristics. In our case, we work with a manifold composed of the values of the desi_3 index, period 2016-2021. The coefficient of variation is the average relative deviation of the parameter values from the mean, expressed as a percentage. If the dispersion of development levels decreases over time, we speak of σ-convergence.

The calculation of relative dispersion is given in formula 1:

$$V_{(\%)} = \frac{\sigma_t}{\bar{x}}(100)\ \%, \tag{1}$$

where: σ_t = the variance of the desi_3 indices at time t and ($\bar{x}$) = the average of the desi_3 indices.

The standard deviation is calculated according to formula 2:

$$\sigma_t = \sqrt{\frac{\sum_{i=1}^{n}(x_{it}-\bar{x})^2}{n}} \tag{2}$$

x_{it} = the desi_3 index of an i-th Member State at time t; ($\bar{x}$) = the average of the desi_3 index, and n denote the number of Member States.

Based on the hypothesis of absolute β-convergence, formula 3 expresses the empirical relationship between growth per Member State and the initial level of development:

$$\frac{1}{T-t_0-1}\ln\left(\frac{X_{iT}}{X_{it_0}}\right) = a + \beta * \log(x_{it_0}) + \varepsilon_i \tag{3}$$

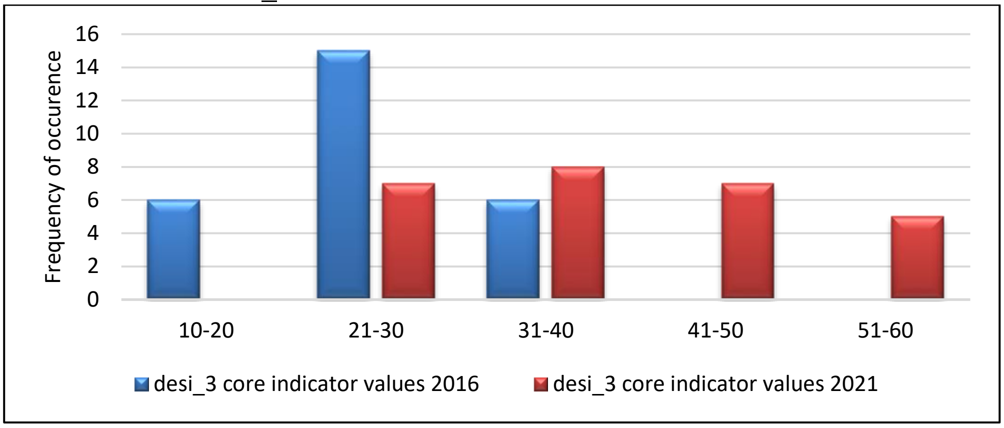
where: $\frac{1}{T-t_0-1}\ln\left(\frac{X_{iT}}{X_{it_0}}\right)$ = the average annual growth rate of the values of the desi_3 index for the *i-th* Member State; t_0 = starting year; T = ending year; $x_{(it_0)}$ = the initial level of development of the desi_3 index; ε_i = the error, which is assumed to be independent and identically distributed; a and β denote the parameters to be estimated.

In this expression, the initial level of development alone explains the rate of catching up. The strength of the effect is indicated by the sign and value of the β coefficient. Univariate linear regression (OLS) was used to estimate the a and β coefficients. However, the estimation would be error-free only in the case of a perfect relationship (r = 1 or r = -1), and therefore εi is the error of the estimate. We use the least-squares procedure based on minimising the squared error to estimate the coefficients a and β. We considered the β-coefficient to be significant only if the empirical significance level (p-value) was less than 5%. However, conditional convergence suggests too much information hidden in a and εi to be extracted on a case-by-case basis, but in this case, we only tested absolute convergence.

Results

In 2016, the desi_3 core indicator values ranged from 10% to 40% (Figure 1), with most Member States in the 21% to 30% (15) range. Finland had the highest score (37.39%), slightly behind but still in the same range (31% - 40%) as Sweden and Denmark. Bulgaria, Latvia, Romania, Poland, and Hungary are at the bottom (10% - 20%).

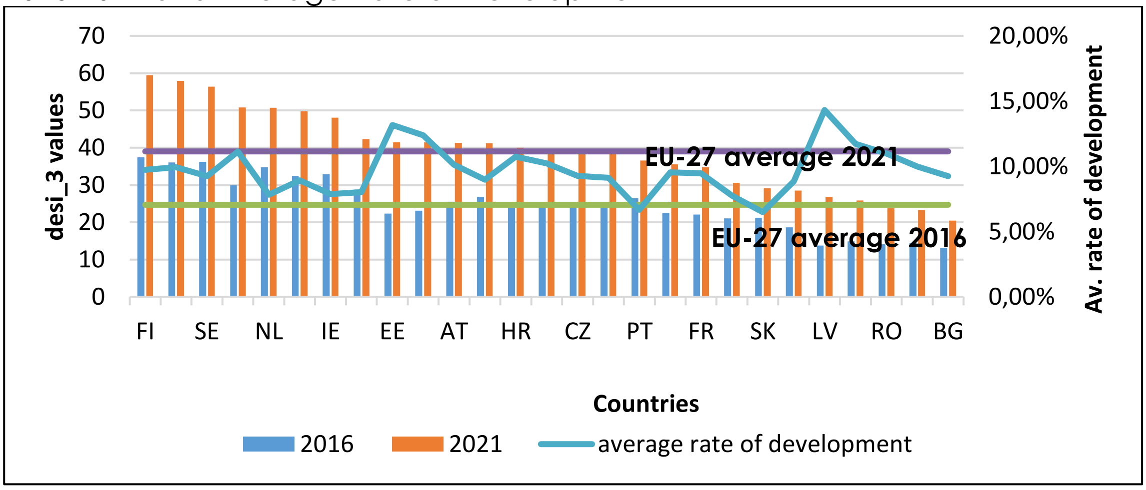
Figure 1
Distribution of Desi_3 Core Indicator Values in 2016 and 2021



Source: Authors' editing based on (European Commission, 2021a)

By 2021, the dispersion of the core indicator values has increased from 3 to 4 ranges, with a range of 21% to 60%. Most Member States are between 31% - and 40 % (8 countries). There has been no significant shift at the top, although Malta and the Netherlands have moved into the top quadrant alongside Finland, Sweden, and Denmark. Looking at the absolute values of the desi_3 core indicator, Bulgaria, Poland, Hungary, and Romania did not improve their position significantly, so the end of the list has not changed. The past six years have not been enough for them to make significant progress in digital inclusion. Croatia was in line with the EU average in 2016 and 2021 with Luxembourg, the Czech Republic, and Spain. Digital technology integration will be highest in Finland in 2021, followed by Denmark and Sweden (Figure 2). On the opposite side are Bulgaria, Hungary, Romania, and Poland. Over the reviewed period, the ranking of countries has not changed significantly for the desi_3 core indicator. Latvia has the highest average growth rate (14.3%) and one of the lowest rates in 2016, so its high growth rate is not surprising, with plenty of catching up. In terms of catching-up rates, Estonia, Malta, and Croatia are next in line, followed by countries that have been and are already at the forefront of digital technology integration, with an average rate of progress of between 9% and 10%.

Figure 2
Country Rankings Based on the Desi_3 Core Indicator. Additional Information from 2016-2021 and Average Rate of Development



Source: Authors' editing based on (European Commission, 2021a)

The basic assumption of β-convergence is that the increase in the desi_3 core indicator is higher in countries already characterised by a lower value. However, this assumption is not confirmed in our case. Although there is a negative correlation between the initial level of development and the average growth rate of the desi_3 core indicator over the period 2016-2021 (-0.0197), the regression coefficient is not significant, as the p-value (0.0556) is greater than α (0.05) (Table 2).

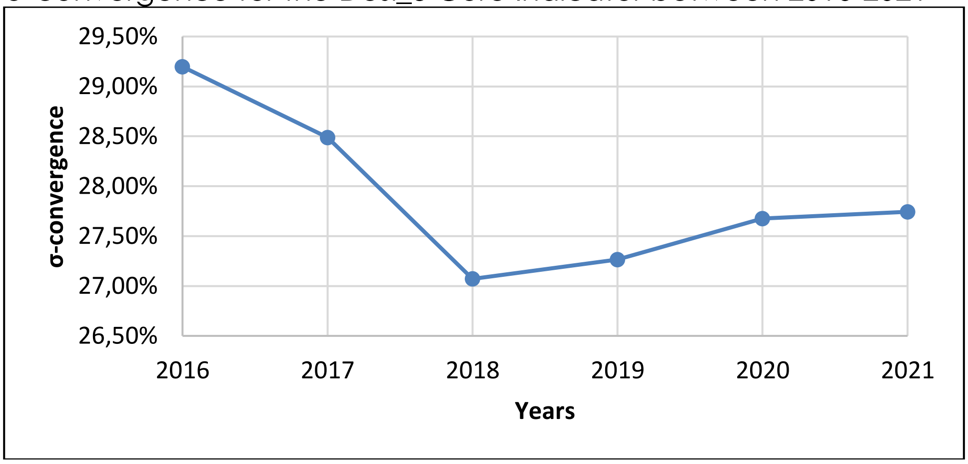
Table 2
Linear Regression Values for the Desi_3 Core Indicator

No. Observations	R-squared	Intercept Coeff.	β	θ	t-value	p-value
27	0,1388	0,1548	-0,0197	-	-2,0075	0,0556

Source: Authors' editing based on (European Commission, 2021a)

The EU-27 Member States converge because the dispersion of the desi_3 core indicator shows a downward trend over time, but this is not the case here. Looking at the σ-convergence between the EU-27 Member States, the relative dispersion is not decreasing, so the desi_3 indicator shows a slight divergence (Figure 3). The differences decreased between 2016 and 2018. Afterward, this trend reversed, and the dispersion of development levels started to increase again.

Figure 3
σ-convergence for the Desi_3 Core Indicator between 2016-2021

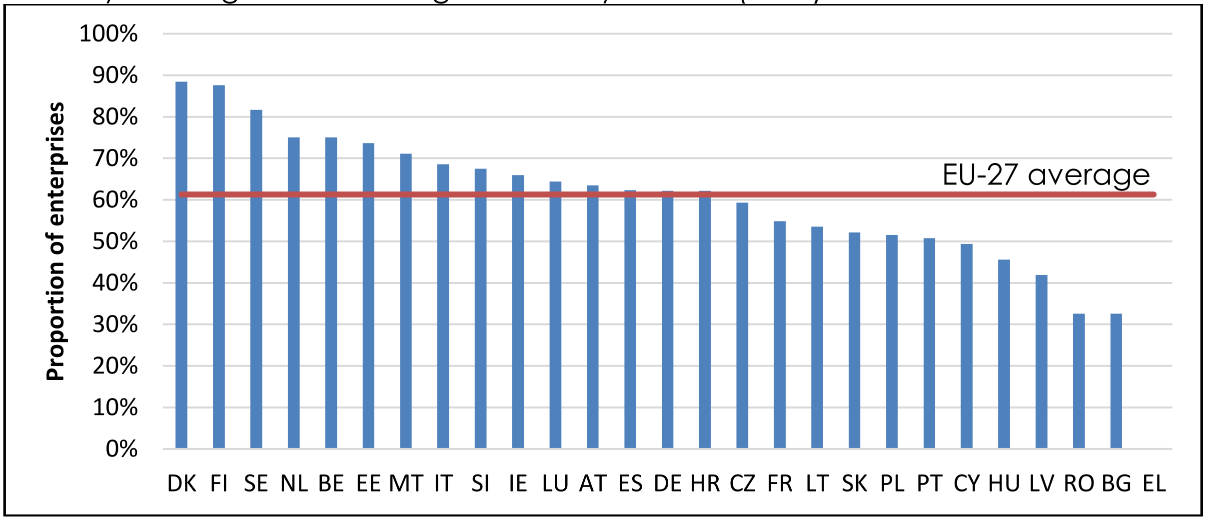


Source: Authors' editing based on (European Commission, 2021a)

The β-convergence contributes to the σ-convergence, as it is essential for the compression and densification of cross-sectional data of countries where the poorer performers grow faster. However, (Ligeti, 2002) has mathematically shown that β-convergence is only necessary but not sufficient for σ-convergence.

Digital intensity (desi_3a), as a sub-dimension, measures the use of different digital technologies at the enterprise level (Figure 4). A company's digital intensity is a function of how many of the following 12 technologies it uses: 1) website; 2) the fastest fixed internet connection has a maximum contracted download speed of at least 30 Mb/s; 3) the website has at least one of the following: description of goods or services, price lists; possibility for visitors to customise or design goods or services online; tracking or status of orders placed; personalised content on the website for regular/returning visitors; 4) businesses where more than 50% of employees used a computer with internet access for business purposes; 5) providing more than 20% of employees with a portable device that allows internet access via a mobile phone network for business purposes; 6) sending e-invoices for automated processing; 7) cloud computing; 8) hiring ICT professionals; 9) companies with at least 1% of turnover from e-commerce; 10) analysing data sets from any source (external or internal); 11) using industrial or service robots; 12) using 3D printers.

Figure 4
Country Rankings based on Digital Intensity of SMEs (2021)

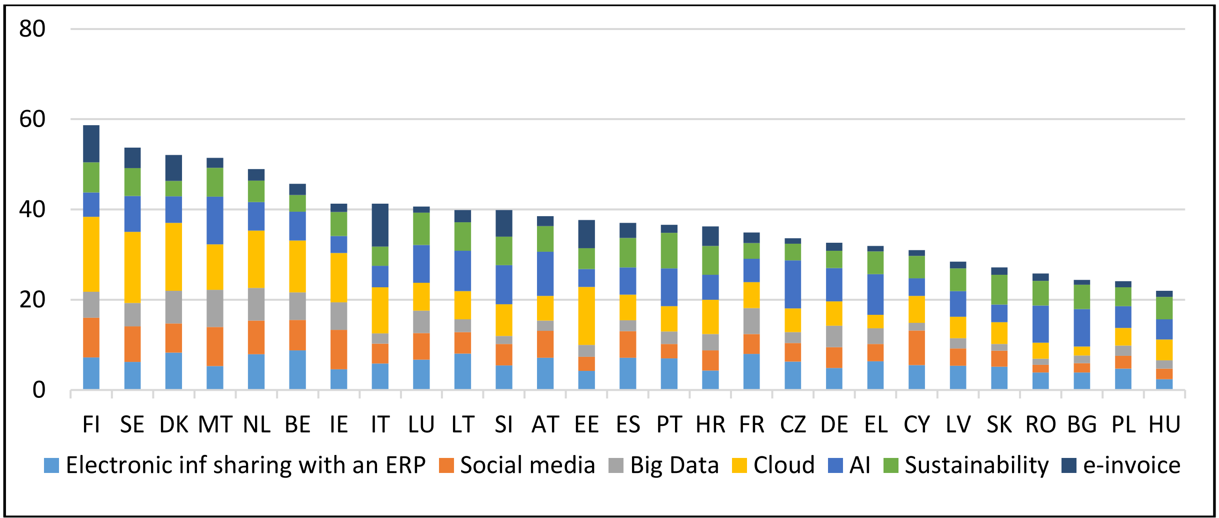


Source: Authors' editing based on (European Commission, 2021a)

Companies in Denmark and Finland have a very high digital intensity, typically using at least between 4 and 9 of the 12 digital technologies listed above. In the enlargement countries of Eastern Europe, the share is far below this, with Bulgaria and Romania at the bottom of the ranking (≈30%). The situation is slightly better in Latvia and Hungary but far from optimal, as the proportion of SMEs that integrate digital technologies is low (between 40% and 45%), but the digital intensity, which would mean combining them, is at most 3. The share of enterprises in the mid-range of the Member States that use digital technologies ranges between 55% and 65%. In terms of intensity of use, this means integrating between 4 and 6 technologies (Eurostat, 2020).

Among the EU Member States, Finland, the Netherlands, Belgium and Denmark lead in the adoption of digital technologies (desi_3b) at enterprise level (Figure 5): social networking sites, corporate blogs and microblogs, multimedia content sharing websites, wiki-based knowledge sharing tools; 3) big data analytics - companies that analyse data sets from any source; 4) cloud computing services - companies that purchase at least one of the following cloud computing services: Enterprise database hosting, accounting software, online case management systems (CRM), operational performance; 5) Artificial intelligence - businesses that use at least two: written language for analysis; machine learning; automation of various work processes or decision making; conversion of spoken language into machine-readable format; identification of objects or people based on images; generation of written or spoken language and AI technologies that allow machines to physically move based on autonomous decisions based on observation of the environment; 6) ICT for environmental sustainability - number of environmentally friendly measures adopted by the company; 7) e-invoices - use of e-invoices that allow automated processing.

Figure 5
Ranking of Countries Based on the Degree of Integration of Digital Technologies in Enterprises (desi_3b) (2021)

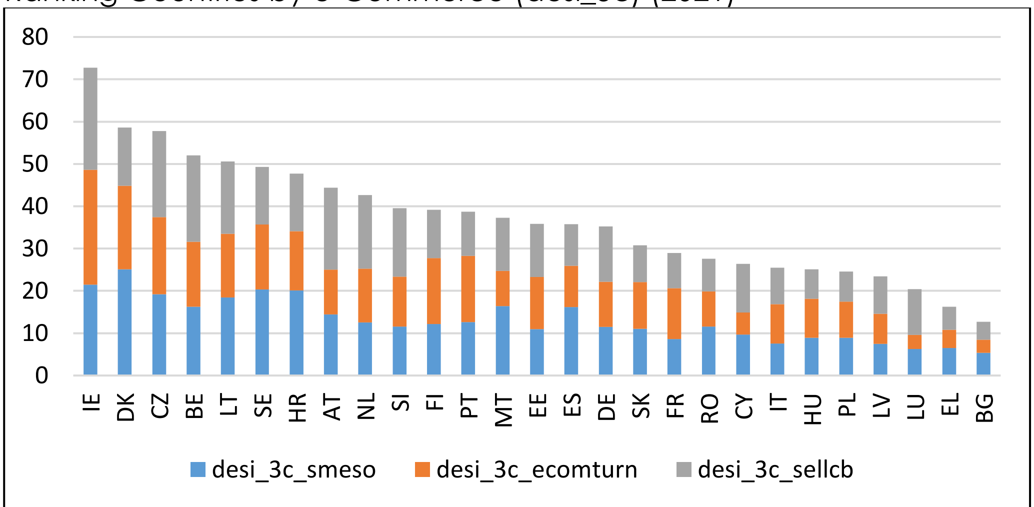


Source: Authors' editing based on (European Commission, 2021a)

Finland leads in social media adoption and use of cloud services, Belgium leads in electronic information sharing, and Maltese companies excel in big data analytics and artificial intelligence. More than 85% of companies report that their use of ICT has led to significant green actions in Portugal, putting them in the first place. Almost 95% of Italian companies issue electronic invoices (32% in the EU-27). Hungary, Poland, Bulgaria, Romania, Slovakia, and Latvia lag far behind in integrating digital technologies into their businesses, with less than a fifth of enterprises using any digital technologies listed here.

Furthermore, in e-commerce (desi_3c), Ireland, the Czech Republic, Denmark, Belgium, and Sweden have the highest aggregate performance (Figure 6). The individual indicators for e-commerce as a sub-dimension are SMEs selling online (at least 1% of turnover), the total turnover from e-commerce, and the share of SMEs selling online across borders (Figure 6).

Figure 6
Ranking Countries by e-Commerce (desi_3c) (2021)



Source: Authors' editing based on (European Commission, 2021a)

In all three of these areas, Ireland is the absolute leader. SMEs in Bulgaria, Greece, Luxembourg, and Latvia have not yet recognised the many opportunities that e-commerce offers.

Discussion

"The Digital Agenda 2030: A European way to achieve the Digital Decade", adopted by the European Parliament in March 2021, is overseen by the "Digital Agenda for the Decade" policy, which sets out the following end-goals for the digital transformation of businesses to achieve the EU-wide digital goals by 2030:

- 75% of EU businesses use cloud services, big data, and artificial intelligence;
- More than 90% of EU SMEs achieve at least a basic level of digital intensity;
- The EU will increase the opportunities for its growing innovative businesses and improve their access to finance, leading to a doubling of unicorns (European Commission, 2021b).

According to classical and neoclassical economics, the main drivers of growth are technological progress and innovation (Barro and Sala-i-Martin, 1995, Romer and Griliches, 1993, Solow, 1956, Solow, 1957, Swan, 1956). Economic growth can only be achieved through the development of human capital and the increased integration of digital technology. The integration and use of digital technology are thoroughly linked to human capital development (Cortright, 2001). Therefore the focus should be on maximising learning opportunities, research, exploration, and development activities at both government and enterprise levels. A framework for digital progress should be developed at the state level and by all companies as a helpful structuring tool to save resources (Grieger et al., 2019). Management's attention to digitalisation and its ability to gather information from inside and outside the company determine digital transformation's success (Bouncken et al., 2021). The state's responsibility cannot be bypassed to facilitate digitisation efforts. It is responsible for developing the proper framework to ensure that it can be applied in the business sector efficiently (Steinbuka et al., 2017).

The desi_3 Core Indicator comprises three sub-dimensions: digital intensity, digital technology integration, and e-commerce. The digital intensity and digital technology integration are primarily the results of the company owners' choices and their ability to recognise the opportunities offered by digitalisation. They need the right skills and financial backing to make the digital transition a reality (Balci, 2021, Caputo et al., 2019, Ehie et al., 2019). The degree of digitisation also varies across economic activities, with high levels of digitisation in, i.e., computing-related sectors, telecommunications, publishing, film and music, television, travel, and tour operators (Şchiopu, 2020). According to the hypothesis (H0), we verify that the change in the desi_3 indices implies no convergence between the Member States. The basic assumption of β-convergence is that the increase in the desi_3 core indicator is higher in countries already characterised by a lower value. However, this assumption is not confirmed statistically in our case, although there is a negative correlation between the initial level of development and the average growth rate of the desi_3 core indicator over the period 2016-2021.

Conclusion

Integrating and correctly using digital technology at the enterprise level is a critical means of differentiation, leading to competitive advantage. By examining and evaluating the values of the DESI index on digital technology integration published by the European Commission, we can conclude that, at present, neither β- nor σ-convergence is observed between the Member States. Although the coefficient β is negative, in principle, the difference between developed and underdeveloped Member States is decreasing, which is not significant (p-value > α). The insignificance means that the growth rate of digital technology integration in the less developed Member States does not exceed that of the developed Member States. The existence of σ-convergence would imply a reduction in the differences between the Member States over time, i.e., a reduction in the relative dispersion between levels of development over time. The absence of β-convergence foreshadowed the absence of σ-convergence since β-convergence is a necessary but not sufficient condition for σ-convergence.

The Member States that joined the European Union after 2004 was typically ranked in the second half of the ranking. Regarding digital technology integration, the main aggregate indicator is that Hungary was ahead of only Bulgaria in 2021 and even one place behind Romania compared to 2016. Romania's average growth rate was one percentage higher per year.

Looking at individual indicators, Hungary has plenty of catching up to do. The share of SMEs with at least basic digital intensity is 46%, below the EU-27 average of 60% but ahead of Bulgaria, Romania, and Latvia. At the EU average level, the 90% target is still far from reaching, with Hungary currently half of the target and Bulgaria and Romania only a third. Among the digital technologies to be applied in business, the Commission highlights the use of big data analytics, cloud services, and artificial intelligence. Hungary is also in the bottom third, ranking 22nd and 23rd, respectively. If we look at the overall ranking (as seven individual indicators in one), it only qualifies for last place. 14% of companies in Hungary use some ERP system (27th), and the same proportion uses social media (25th). E-invoices for automated processing are 13% of Hungarian businesses, still only a third of the EU average. In e-commerce, Hungary's gap compared to the EU average is not so evident, with a more significant gap in cross-border online sales. Considering the low level of digital penetration among businesses, 22nd place in e-commerce is not such a bad result.

In conclusion, to increase the use of digital technologies in companies is to educate the business community about the diversity of applications of digital technologies, as many of these innovative technologies are seen as a source of fear rather than an opportunity. At the same time, it is essential to remember that digital technology-based developments have a high financial cost, which the development of human resources must match. It is, therefore, necessary to include the costs of human resource deployment, training, and retraining in calculating the return on investment. The state should support digital development through various tendering procedures, which is also unsatisfactory. Developing the ICT sector as an integrated element with the business concerned would also be essential, thus sacrificing independence to implement projects effectively.

We believe, especially in the case of SMEs, that in many cases, entrepreneurs are more likely to undertake various activities related to digitalisation instinctively rather than consciously, considering the potential benefits/disadvantages.

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