

PROFILES OF EUROPEAN UNION COUNTRIES IN THE FIELD OF DIGITAL AND KNOWLEDGE-BASED ECONOMIES

Maryna Tatar¹, Maryna Mashchenko², Olena Klimenko³

Abstract. This article aims to create country profiles for European Union *Member States*, based on indicators that capture digital access and usage, business digitalisation and e-commerce, as well as human capital and innovation capacity. The empirical results reveal significant differences between countries in the adoption of e-commerce. Northern and Western European countries have a high proportion of enterprise turnover generated through e-commerce and a high proportion of firms that receive online orders. In contrast, several Southern and Eastern European economies have markedly lower levels. The distribution of human resources in science and technology is marked by significant disparities, with pronounced concentrations observed in knowledge-intensive economies such as Luxembourg, Sweden, Ireland, and the Netherlands, and persistently lower shares evident in several Eastern and Southern European countries. These disparities are closely aligned with differences in innovation capacity, as reflected by research and development expenditure. The analysis confirms a pronounced North–West versus South–East divide in R&D intensity, with only a limited group of countries consistently exceeding the 3% of GDP benchmark. Despite the fact that domestic internet access is almost universal throughout the EU, the intensity of digital usage by individuals varies considerably, thereby highlighting a persistent digital usage gap. This finding indicates that access alone is inadequate to ensure effective participation in the digital economy. The conducted cluster analysis identifies three distinct digital and knowledge economy profiles, ranging from highly digitalised and innovation-driven economies to countries with weaker digital engagement and limited innovation capacity. The findings emphasise that digital transformation in the EU is influenced not only by infrastructure availability but also by human capital, innovation systems, and the effective use of digital technologies. The findings of this study carry significant ramifications for the digital and cohesion policies of the European Union, underscoring the necessity for targeted strategies that address inherent disparities and foster inclusive digital and knowledge-based growth.

Keywords: digitalisation, knowledge economy, e-commerce, human capital, innovation capacity, European Union, cluster analysis.

JEL Classification: O31, O32, O33, O34

1. Introduction

Digitalisation has become a central driver of economic transformation in the European Union, reshaping production structures, innovation processes, and the functioning of the economy. In the preceding decade, digital technologies have precipitated a paradigm shift in the manner by which individuals access information, the manner by which firms organise

production and reach markets, and the manner by which economies generate, diffuse and exploit knowledge. The strategic importance of digitalisation within the EU has been reinforced by major policy initiatives, including the Digital Single Market strategy, the Digital Decade targets, and the broader agenda of smart, sustainable, and inclusive growth. These frameworks emphasise not only the expansion of

¹ National Aerospace University "Kharkiv Aviation Institute", Ukraine (*corresponding author*)

E-mail: m.tatar@khai.edu

ORCID: <https://orcid.org/0000-0002-1111-7103>

² National Technical University "Kharkiv Polytechnic Institute", Ukraine

E-mail: maryna.mashchenko@khp.edu.ua

ORCID: <https://orcid.org/0000-0002-8863-6040>

³ Simon Kuznets Kharkiv National University of Economics, Ukraine

E-mail: olena.klimenko@hneu.net

ORCID: <https://orcid.org/0000-0002-2573-9333>



digital infrastructure but also the diffusion of digital technologies among businesses, the development of digital skills, and the strengthening of innovation ecosystems.

2. Literature Review

As is evidenced by the extant literature on the digital economy, digitalisation exerts a significant influence on the shaping of economic growth, innovation processes, and human capital development.

2.1. Digitalisation and Economic Growth

Digitalisation has been extensively documented as a pivotal catalyst for economic growth in advanced economies, particularly within the European context. Empirical evidence suggests that digital transformation contributes positively to GDP growth by enhancing productivity, facilitating new business models, and expanding market access (Mura & Donath, 2023). The authors demonstrate that digitalisation, measured by composite indices such as the Digital Economy and Society Index (DESI), is significantly and positively associated with economic performance across EU Member States. This suggests that countries with more advanced digital economies tend to experience stronger growth outcomes. The findings of this study emphasise the significance of digital adoption as a determining factor in macro-economic growth within the European Union. At the regional and sustainability levels, digital transformation has been linked not only to economic performance but also to broader developmental outcomes. In their 2023 study, Bocean and Vărzaru (2023) emphasised the correlation between the utilisation of digital tools by enterprises, including e-commerce and advanced digital technologies such as cloud computing and big data, and the national economic performance of the respective countries, as well as their progress in achieving sustainable development goals. The role of e-commerce in this relationship is particularly pronounced, serving as a mediator of digital intensity and economic inclusion within digital economies.

2.2. Digitalisation and Innovation

A recurrent theme in extant literature pertains to the nexus between digitalisation and innovation. This relationship is both structural and dynamic in nature: digital technologies provide the necessary infrastructure and capabilities for innovation processes, while innovation, in turn, accelerates digital adoption. Sánchez Ramírez et al. (2022) posit that the integration of digital tools with strategic knowledge management practices within firms serves to enhance innovation capabilities. The authors emphasise that digitalisation

facilitates knowledge flows and organisational learning, which in turn engenders innovation outcomes. Research conducted in the European context also indicates that the impact of digitalisation on innovation is contingent on firm characteristics and regional conditions. Empirical studies on European small and medium-sized enterprises (SMEs) demonstrate that digital diffusion enhances innovation performance, particularly when combined with absorptive capacity and human capital quality. Hassan et al. (2024) demonstrate that SMEs with higher digital adoption exhibit stronger innovation outcomes, with digital tools enabling both incremental and novel innovations.

However, it should be noted that the relationship is not universally linear. It is evident that a paucity of evidence exists to substantiate the hypothesis that digital tools alone are capable of guaranteeing innovation, in the absence of formal R&D activities. Empirical studies on European SMEs demonstrate that R&D continues to be a pivotal catalyst for innovation performance, and that the integration of digital technologies may only augment innovation in firms that have already committed significant resources to R&D activities. This finding underscores the significance of complementary innovation inputs (Radicić & Petković, 2023).

2.3. Human Capital in the Digital and Knowledge Economy

Human capital, particularly in the fields of science, technology, engineering and mathematics, is recognised as a key driver of digitalisation and innovation. Studies of Central and Eastern European economies indicate that the quality of human capital significantly impacts countries' ability to reap the benefits of digital transformation, primarily by boosting productivity, promoting entrepreneurial activity, and reinforcing national innovation systems (Grigorescu et al., 2021). Studies analysing the relationship between digitalisation and innovation emphasise the importance of digital skills and lifelong learning in achieving sustainable digital and innovation outcomes. For example, Rojas et al. (2024) point out that innovation and digitalisation are mutually reinforcing processes. However, both require an advanced workforce, particularly one with ICT proficiency, in order to maximise the potential for digital growth.

2.4. The Development of E-Commerce and the Digital Economy

Although fewer studies explicitly focus on e-commerce adoption at the macro level within the EU, the existing literature recognises e-commerce as a key component of modern digital economies. Research in marketing and digital strategy emphasises

that e-commerce adoption affects the transformation of the economic landscape by expanding market reach, lowering transaction costs and enabling firms to integrate digital channels into their core business models (Rolando & Mulyono, 2025). This highlights e-commerce's role in mediating between digital infrastructure and broader economic performance, particularly when supported by coherent institutional and technological frameworks.

2.5. Research Gaps

The analysed literature collectively portrays digitalisation as a multifaceted phenomenon with far-reaching implications for economic growth, innovation performance and the deployment of human capital within the European Union. Crucially, the benefits of digitalisation are amplified when digital infrastructure is coupled with robust innovation systems and high-quality human capital. However, disparities remain among EU Member States in their ability to realise these benefits, with structural variations in education, R&D investment and SME digital adoption influencing national digital and innovation profiles. Although research on digitalisation in Europe has expanded rapidly, much of the existing literature focuses on individual aspects, such as digital infrastructure, innovation performance or economic growth, in isolation. Fewer studies have examined the combined impact of digital access and use, business digitalisation through e-commerce, and knowledge-based human capital on differentiated national profiles. Consequently, the important interactions between these elements, particularly in a cross-country EU context, remain insufficiently explored.

This article aims to create country profiles for EU Member States based on indicators measuring digital access and usage, business digitalisation and e-commerce, and human capital and innovation capacity. Considering these dimensions together provides a comprehensive perspective on how digital transformation contributes to development patterns within the EU.

3. Methodology and Data

This analysis uses a set of indicators that reflect the level of access to and use of digital technologies, the prevalence of e-commerce, as well as human capital and innovation potential. These include indicators of internet usage by individuals and households, commercial activity on the internet, the intensity of research and development, the production of high-tech products, and human resources in the field of science and technology in 2024 in the countries of the European Union, namely:

1. Digital access and usage:

- Level of internet access (households, percentage of households (LIA));
- individuals using the internet for finding information about goods and services, percentage of individuals (IFG).

2. Business digitalisation and e-commerce:

- Share of enterprises' turnover on e-commerce, percentage of turnover (EEC);
- enterprises having received orders online (at least 1%), percentage of enterprises (ONL).

3. Human capital and innovation capacity:

- Research and development expenditure by sector of performance, percentage of gross domestic product (RDE);
- human resources in science and technology, percentage of population in the labour force (HRST).

The analysis is divided into three stages. Initially, the application of descriptive statistics facilitates the examination of cross-country disparities and tendencies in the designated indicators. Secondly, a comparative analysis is applied to identify patterns and disparities across EU Member States in terms of digital access and usage, e-commerce intensity, and human capital and innovation capacity. Thirdly, a cluster analysis is conducted to identify groups of countries with similar digital and knowledge economy profiles. A hierarchical clustering analysis was performed, and a dendrogram (horizontal tree clustering plot) was constructed, which revealed the presence of three distinct clusters. Subsequently, the k-means clustering algorithm was employed to assign individual observations to clusters and to characterize cluster-specific properties. The k-means clustering algorithm is employed in this study, as it is well suited to the identification of homogeneous groups in multidimensional datasets. In order to enhance the robustness and policy relevance of the results, selected cluster representatives are benchmarked against the Digital Economy and Society Index (DESI), which has been developed by the European Commission. This enables the contextualisation of the identified clusters within a broader framework of EU digital performance, thereby facilitating the interpretation of disparities in digital infrastructure, business digitalisation, skills, and digital public services.

4. Results

The data on the share of enterprises' turnover generated through e-commerce and on the proportion of enterprises receiving online orders show substantial cross-country variation among the selected European economies (Figure 1).

The proportion of turnover generated by enterprises through e-commerce ranges from below 7.86% in Bulgaria and Greece to almost 30% in Denmark, Finland and Belgium. This suggests that there are

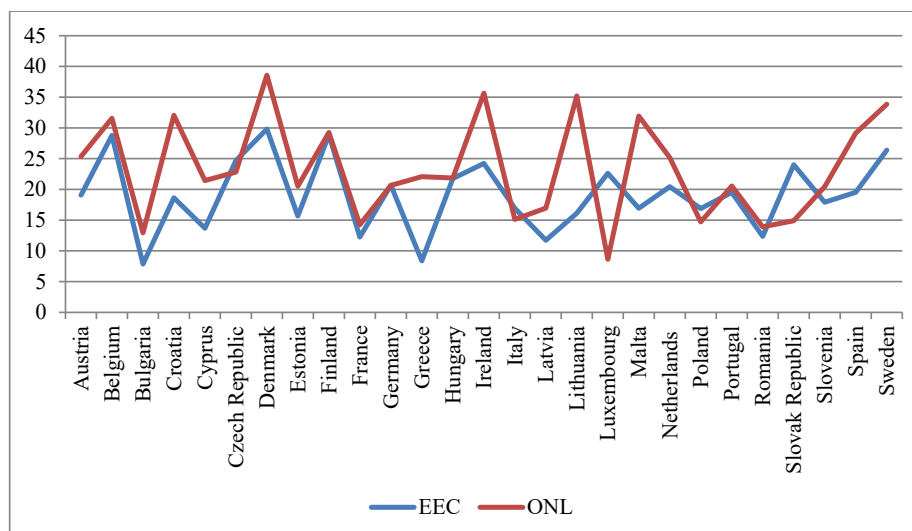


Figure 1. Share of enterprises' turnover on e-commerce, percentage of turnover (EEC) and enterprises having received orders online (at least 1%), percentage of enterprises (ONL)

Source: own processing based on Eurostat (2026)

markedly different levels of e-commerce intensity across economies. The proportion of enterprises that receive online orders varies even more widely, from 8.65% in Luxembourg to almost 38.58% in Denmark. Relatively high participation is also observed in Ireland, Lithuania, Sweden and Spain. In several countries, including Croatia, Greece, Lithuania and Malta, the proportion of enterprises receiving online orders is much higher than the proportion of turnover generated through e-commerce. This indicates a widespread adoption of online sales channels with comparatively low turnover. In contrast, Luxembourg shows the opposite pattern: a relatively high proportion of turnover is generated through e-commerce, but only a small proportion of enterprises receive online orders. This implies that e-commerce turnover is concentrated among a small number of firms. These results emphasise the heterogeneity in the adoption of online ordering by enterprises and the economic importance of e-commerce in different European countries.

As shown in Figure 2, the HRST indicator ranges from a minimum of 30.6% in Romania to a maximum of 71.9% in Luxembourg, indicating pronounced disparities in the availability of science- and technology-related human capital.

The countries with the highest HRST shares are Luxembourg (71.9%), Ireland (66.3%), Sweden (65.3%), the Netherlands (64.7%) and Denmark (62.1%). This reflects their strong specialisation in knowledge-intensive activities. A second group of countries with above-average HRST levels comprises Belgium, Cyprus, Finland, France, Lithuania and Austria, all of which exceed 55%. In contrast, Southern and Eastern European countries tend to have lower HRST shares. The Slovak Republic (43.8%), Portugal

(43.3%), Greece (43.2%), Bulgaria (43.0%) and Italy (39.7%) cluster around the lower end of the distribution. Romania, meanwhile, represents a clear outlier with the weakest HRST intensity. The data reveal a clear concentration of human resources in science and technology in Northern and Western Europe. In contrast, lower HRST shares persist in several Central, Eastern and Southern European economies. This suggests structural differences in labour market composition and innovation capacity.

Figure 3 shows that there are significant differences in innovation intensity, as indicated by research and development expenditure. Values range from 0.46% of GDP in Romania to 3.57% in Sweden, revealing a gap of over seven times between the lowest and highest investors in R&D. The countries with the highest R&D expenditure (RDE) are Sweden (3.57%), Belgium (3.36%), Austria (3.26%), Finland (3.22%), Germany (3.13%) and Denmark (3.01%). All of these exceed the 3% benchmark commonly associated with advanced, innovation-driven economies. These countries demonstrate a strong commitment to knowledge creation and technological development.

The medium R&D expenditure (RDE) group includes the Netherlands (2.29%), France (2.18%), Slovenia (2.16%) and Estonia (1.99%), reflecting a moderate yet consistent investment in research and innovation. By contrast, most Southern and Eastern European countries allocate less than 1.5% of their GDP to R&D. Bulgaria (0.77%), Cyprus (0.65%), Malta (0.51%) and Romania (0.46%) are at the lower end of this scale, suggesting limited R&D capacity. The data clearly show a North–West versus South–East divide in R&D investment. Higher expenditure is concentrated in Northern and Western Europe, while several Central,

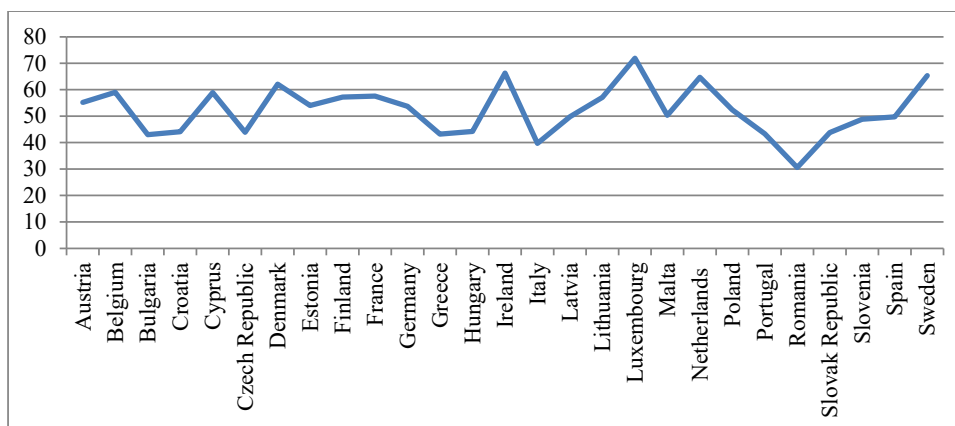


Figure 2. Human resources in science and technology (HRST), percentage of population in the labour force

Source: own processing based on Eurostat (2026)

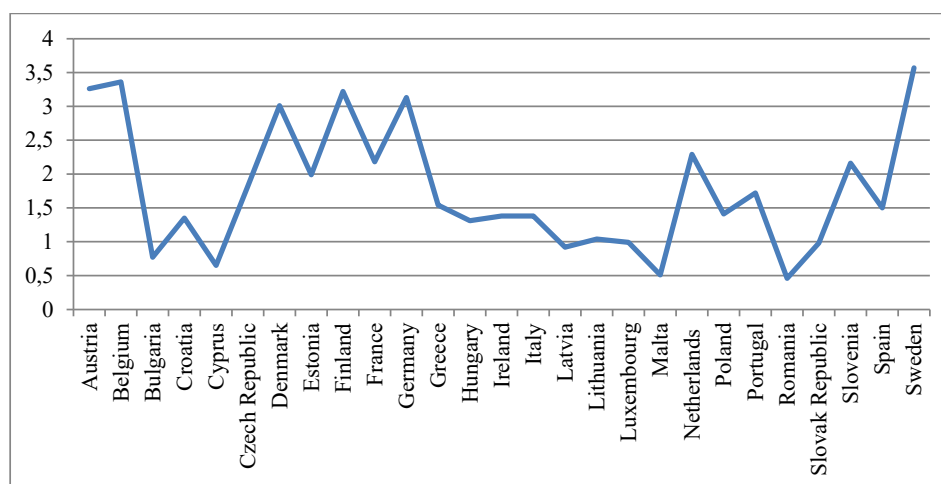


Figure 3. Research and development expenditure by sector of performance, percentage of GDP

Source: own processing based on Eurostat (2026)

Eastern and Southern European economies have persistently lower levels.

Figure 4 shows that the level of internet access among households (LIA) is uniformly high across countries, with values ranging from 86.9% in Greece to 99.04% in the Netherlands. This indicates that basic digital infrastructure is almost universal.

Most countries record LIA levels above 90%, which suggests that there is limited variation in household connectivity across countries. In contrast, individuals who use the internet to search for information about goods and services display substantially greater dispersion. IFG values range from 56.3% in Romania and 58.1% in Italy to 96.3% in the Netherlands and 94.1% in Denmark, highlighting differences in the intensity rather than the accessibility of digital use. Countries such as the Netherlands, Denmark, Ireland, Sweden and Finland have very high LIA levels and high IFG values, reflecting advanced digital engagement.

Conversely, several countries with high levels of household internet access – namely Italy, Romania, Bulgaria and Poland – exhibit relatively low internet usage, indicating a gap between connectivity and usage. The data suggest that, although internet access has reached saturation levels, there are still significant cross-country differences in digital behaviour and effective use.

The members of the clusters are presented in Table 1.

The mean values for each cluster are presented in Figure 5, while the distances between clusters are shown in Figure 6.

Figure 7 shows the average values of the chosen indicators for the three groups of countries, revealing significant variations in their digitalisation and innovation profiles. Cluster 3 exhibits the highest average levels for most indicators, particularly with regard to human resources in science and technology, the level of internet access in households and the

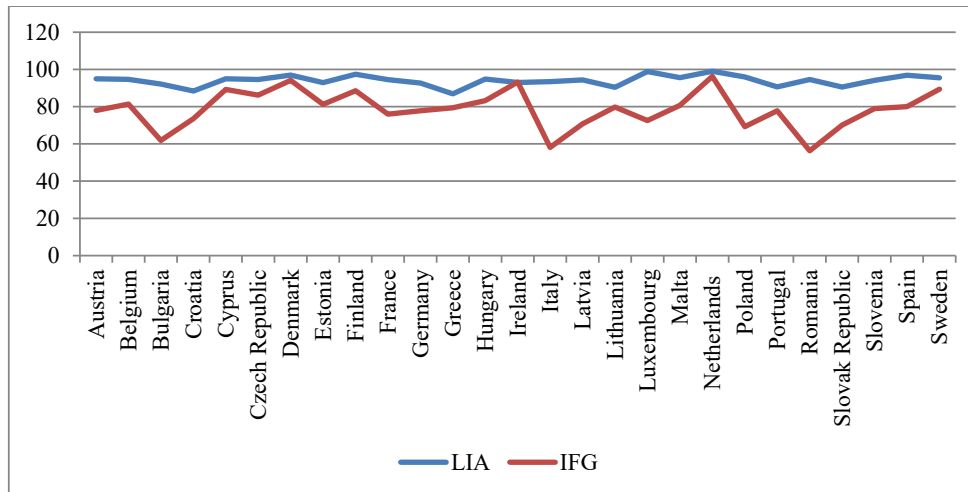


Figure 4. Level of internet access, percentage of households (LIA) and individuals using the internet for finding information about goods and services, percentage of individuals (IFG)

Source: own processing based on Eurostat (2026)

Table 1
Members of the clusters

Members of Cluster Number 1 (Spreadsheet3) and Distances from Respective Cluster Center Cluster contains 15 cases		Members of Cluster Number 2 (Spreadsheet3) and Distances from Respective Cluster Center Cluster contains 6 cases		Members of Cluster Number 3 (Spreadsheet3) and Distances from Respective Cluster Center Cluster contains 6 cases	
	Distance		Distance		Distance
C_1 Austria	2.09230	C_3 Bulgaria	3.216041	C_2 Belgium	4.146994
C_4 Croatia	5.77958	C_15 Italy	3.063453	C_7 Denmark	3.286681
C_5 Cyprus	5.28177	C_16 Latvia	4.075211	C_9 Finland	2.842235
C_6 Czechia	5.05336	C_21 Poland	4.432736	C_14 Ireland	2.872204
C_8 Estonia	1.80608	C_23 Romania	6.240480	C_20 Netherlands	4.750847
C_10 France	5.14356	C_24 Slovak Republic	4.530887	C_27 Sweden	1.457280
C_11 Germany	2.00440				
C_12 Greece	5.85018				
C_13 Hungary	3.84534				
C_17 Lithuania	5.57989				
C_18 Luxembourg	10.95415				
C_19 Malta	3.81906				
C_22 Portugal	3.90545				
C_25 Slovenia	1.68872				
C_26 Spain	3.03293				

Source: own processing

proportion of individuals who use the internet to find information about goods and services. This indicates a digitally advanced and knowledge-intensive profile. Cluster 1 shows intermediate values across most dimensions, suggesting moderate development in business digitalisation and innovation capacity. Cluster 2 consistently records the lowest mean values for e-commerce turnover, the proportion of enterprises receiving online orders, the proportion of human resources in science and technology, and individual internet use. This reflects comparatively

weaker digital and innovation performance. Research and development expenditure appears low and similar across all clusters, suggesting that it contributes less to cluster differentiation than the other indicators. Therefore, the plot suggests that clustering is primarily driven by differences in digital access, digital use and human capital, rather than by the intensity of research and development.

Descriptive statistics for the digital and knowledge economy indicators across the three clusters are presented in Table 2.

Variable	Cluster Means (Spreadsheet3)		
	Cluster No. 1	Cluster No. 2	Cluster No. 3
EEC	17.82733	14.95833	26.41667
ONL	23.12400	14.75333	32.33833
HRST	51.72667	43.21667	62.43333
RDE	1.67667	0.98667	2.80500
LIA	93.38800	93.47667	96.05500
IFG	79.60467	64.37500	90.47334

Figure 5. Cluster means

Source: own processing

Cluster Number	Euclidean Distances between Clusters (Spreadsheet3)		
	No. 1	No. 2	No. 3
No. 1	0.000000	63.85767	66.6379
No. 2	7.991099	0.00000	250.1472
No. 3	8.163202	15.81604	0.0000

Figure 6. Distances between clusters

Source: own processing

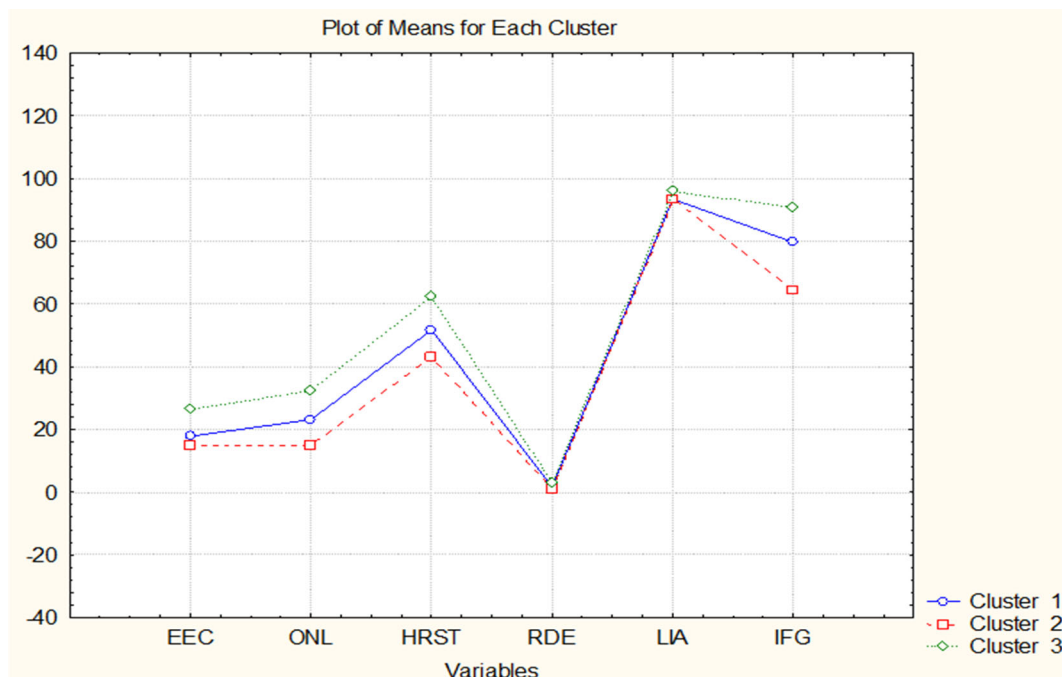


Figure 7. Plot of means for each cluster

Source: own processing

Cluster 1 is characterised by average mean values across most indicators. The mean values for EEC (17.83) and ONL (23.12) are intermediate relative to the other clusters, while HRST has a high mean value of 51.73. RDE remains relatively low (1.68) with limited variability. LIA (93.39) and IFG (79.60) are high,

suggesting strong performance in these areas, although IFG shows moderate dispersion (SD = 4.33).

Compared to the other clusters, Cluster 2 displays lower mean values for EEC (14.96), ONL (14.75), HRST (43.22) and IFG (64.38). This cluster also exhibits the lowest mean value for RDE (0.99). There

Table 2

Descriptive statistics for the indicators

Descriptive Statistics for Cluster 1 (Spreadsheet2) Cluster contains 15 cases			
	Mean	Standard	Variance
EEC	17.82733	4.202862	17.66405
ONL	23.12400	6.887511	47.43781
HRST	51.72667	7.916571	62.67210
RDE	1.67667	0.793263	0.62927
LIA	93.38800	3.175590	10.08437
IFG	79.60467	4.334611	18.78885
Descriptive Statistics for Cluster 2 (Spreadsheet2) Cluster contains 6 cases			
EEC	14.95833	5.602794	31.39130
ONL	14.75333	1.347808	1.81659
HRST	43.21667	7.740909	59.92167
RDE	0.98667	0.364070	0.13255
LIA	93.47667	1.908755	3.64335
IFG	64.37500	6.453107	41.64259
Descriptive Statistics for Cluster 3 (Spreadsheet2) Cluster contains 6 cases			
EEC	26.41667	3.568948	12.73739
ONL	32.33833	4.773139	22.78286
HRST	62.43333	3.676774	13.51867
RDE	2.80500	0.825027	0.68067
LIA	96.05500	2.158821	4.66051
IFG	90.47334	5.333497	28.44619

Source: own processing

is relatively little variability within Cluster 2 for ONL (SD = 1.35) and RDE (SD = 0.36), indicating internal homogeneity. However, greater dispersion is observed for EEC and HRST. LIA remains high at 93.48, comparable to Cluster 1.

Cluster 3 shows consistently higher mean values across all indicators. Notably, EEC (26.42), ONL (32.34), HRST (62.43), RDE (2.81) and IFG (90.47) are the highest among the three clusters. LIA also reaches its maximum mean value (96.06) with relatively low variability. Overall, Cluster 3 demonstrates high performance and comparatively low dispersion for several indicators, suggesting it is a more homogeneous and high-performing group. In summary, Cluster 2 shows lower performance across most indicators. Cluster 1 shows intermediate performance, while Cluster 3 is characterised by consistently high indicator values.

The clusters are represented by Slovenia (Cluster 1), Italy (Cluster 2) and Sweden (Cluster 3). Table 3 shows the Digital Economy and Society Index (DESI) values for each cluster representative. The DESI is a composite index developed by the European Commission to evaluate and compare the digital performance of EU Member States, providing a multidimensional measure of their progress in digital transformation.

Sweden (Cluster 3) consistently outperforms Slovenia (Cluster 1) and Italy (Cluster 2) across most digital economy indicators. This is particularly evident in terms of digital infrastructure, SME digitalisation,

AI adoption, the number of ICT specialists, and the provision of public digital services for businesses. Italy demonstrates a moderate level of performance, with strong 5G coverage and edge nodes, but lower AI adoption and a smaller number of unicorn companies. Meanwhile, Slovenia demonstrates solid infrastructure coverage and e-health access, with moderate SME digitalisation. Despite high 5G coverage across all three countries, differences in fibre deployment, SME digitalisation and AI adoption suggest that advanced digital economy performance cannot be guaranteed by infrastructure alone. Cluster 1 and 2 countries may benefit from incentives to encourage SMEs to adopt digital technologies and integrate AI. Sweden's strong performance highlights the potential impact of integrated digital strategies spanning skills, businesses, and public services. All three cluster representatives exceed or approach EU averages in key areas. However, disparities remain in innovation metrics such as unicorn companies and AI adoption, highlighting areas in which targeted policies and investments are needed.

It is evident that, upon the identification of clusters and their respective characteristics, strategies for the digital and knowledge economies can be developed (see Table 4).

These cluster-specific strategies offer a targeted approach to improving the performance of the digital and knowledge economies by addressing the strengths and weaknesses of each cluster.

Table 3
DESI 2025 (year 2024) for cluster representatives

Digital Decade KPI	Slovenia	Italy	Sweden	EU
Fixed Very High Capacity Network (VHCN) coverage	79.6%	70.7%	89.7%	82.5%
Fibre to the Premises (FTTP) coverage	79.6%	70.7%	85.6%	69.2%
Overall 5G coverage	96.7%	99.5%	98.6%	94.3%
Edge Nodes (estimate)	16	152	63	2257
SMEs with at least a basic level of digital intensity (2)	67.6%	70.2%	86.6%	72.9%
Cloud	–	–	–	–
Artificial Intelligence	20.9%	8.2%	25.1%	13.5%
Data analytics	–	–	–	–
AI or Cloud or Data analytics	–	–	–	–
Unicorns	0	9	39	286
At least basic digital skills	–	–	–	–
ICT specialists	4.3%	4.0%	8.6%	5.0%
eID scheme notification	Yes	Yes	Yes	–
Digital public services for citizens	78.6	83.6	85.9	82.3
Digital public services for businesses	85.0	80.9	90.4	86.2
Access to e-Health records	87.5	84.1	77.9	82.7

Source: DESI indicators (2026)

Table 4
Digital and knowledge economy strategies

Cluster	Profile	Strengths	Weaknesses	Recommended digital and knowledge economy strategies
Cluster 1	Intermediate digitalisation and knowledge economy performance	High household internet access and moderate internet use for goods/services; moderate human resources in science and technology; average e-commerce turnover	Lower R&D intensity; moderate SME digital adoption; gaps in AI adoption and unicorn creation	<ul style="list-style-type: none"> - Encourage SMEs to adopt digital tools, e-commerce, and AI solutions; - expand digital skills training; - strengthen targeted R&D support programmes, R&D incentives and public-private innovation partnerships; - strengthen collaboration between research institutions and industry; - promote high-tech entrepreneurship and startup incubation; - enhance digital public services and e-government platforms; - support integration of sustainable and green digital technologies.
Cluster 2	Lower performance in digital and knowledge economy indicators	Basic digital infrastructure in place	Lowest e-commerce participation; low HRST and R&D expenditure; low AI adoption and innovation outcomes	<ul style="list-style-type: none"> - Invest in R&D and innovation hubs and collaborate with universities to increase knowledge-intensive activities; - implement digital literacy and e-commerce training programmes; - promote STEM education and ICT specialisation; - facilitate AI adoption and high-tech startup creation; - improve access to digital public services and online platforms; - encourage cross-border knowledge exchange and EU funding programmes.
Cluster 3	High-performing, digitally advanced, and knowledge-intensive	Highest e-commerce turnover, HRST, and R&D; advanced infrastructure, high AI adoption, strong human capital, and innovation ecosystem	Minor gaps in high-growth startups and frontier technologies	<ul style="list-style-type: none"> - Promote AI, data analytics, cloud adoption in SMEs; - strengthen high-tech entrepreneurship and support unicorn startups; - encourage international partnerships and R&D co-operation; - invest in sustainable and smart digital solutions.

Source: own processing

5. Discussions

The study highlights significant differences in digitalisation, e-commerce adoption and innovation capacity between EU countries. This confirms that digital infrastructure alone is insufficient for active

participation in the knowledge economy. Although household internet access is similar, online commercial activity and intensive digital use vary considerably, particularly among SMEs. This is consistent with the findings of Brodny and Tutak (2024). E-commerce

intensity differs markedly, with Northern and Western European countries demonstrating broader adoption and higher turnover, while Southern and Eastern Europe lag behind.

Human resources in science and technology are concentrated in Northern and Western Europe, which reinforces the link between digital skills, innovation capacity and economic performance. Countries with lower HRST and R&D expenditure face challenges in leveraging digitalisation for innovation, as reported by Duff et al. (2025) and Duarte & de Oliveira Carvalho (2024). Cluster analysis reveals a North–West versus South–East divide. While the level of basic connectivity is high across clusters, disparities in knowledge economy performance are driven by differences in digital use, human capital and e-commerce adoption. The findings of this study demonstrate that the digital transformation within the European Union is characterised by heterogeneity and multi-dimensionality. This necessitates the implementation of targeted interventions to foster digital engagement in regions that are exhibiting lagging trends.

6. Conclusions and Recommendations

This study provides a thorough evaluation of the levels of digitalisation, e-commerce and innovation

capacity in EU countries. The results reveal significant disparities between countries in terms of digital engagement and knowledge economy development. Cluster analysis identified three distinct country profiles: high-performing (Cluster 3), intermediate (Cluster 1) and lower-performing (Cluster 2). High-performing countries demonstrate robust human capital in science and technology, extensive online commercial activity, and greater R&D intensity, suggesting an integrated approach to digital and knowledge economy development. By contrast, lower-performing countries demonstrate limited innovation capacity, lesser levels of SME digitalisation and weaker human resources in technology-intensive sectors. This suggests that they face structural challenges in leveraging digitalisation fully for economic growth. The study confirms that digital infrastructure alone does not guarantee performance in the knowledge economy. Effective digital adoption, investment in human capital and innovation capacity are key drivers of economic competitiveness in the EU. These findings highlight the need for targeted policies to promote the digitalisation of SMEs, encourage investment in R&D, and develop science- and technology-related skills, particularly in Southern and Eastern European economies that are lagging behind.

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