

## РОЗДІЛ 2. СВІТОВЕ ГОСПОДАРСТВО І МІЖНАРОДНІ ЕКОНОМІЧНІ ВІДНОСИНИ

### FROM CONVERGENCE TO DIVERGENCE? A TEMPORAL CLUSTER ANALYSIS OF ECONOMIC GROWTH, DIGITALISATION, AND R&D IN THE EU ВІД КОНВЕРГЕНЦІЇ ДО ДИВЕРГЕНЦІЇ? АНАЛІЗ ЧАСОВИХ КЛАСТЕРІВ ЕКОНОМІЧНОГО ЗРОСТАННЯ, ЦИФРОВІЗАЦІЇ ТА НДДКР В ЄС

*The article conducts a comparative cluster analysis of 27 EU countries in 2017 and 2022 on three key indicators: GDP growth per capita, Digital Economy and Society Index (DESI), and research and development (R&D) spending. The selected years reflect the pre- and post-pandemic economic landscape. The analysis reveals three stable types of clusters: innovation and digitalisation leaders, high-growth but low-innovation economies, and a group of stagnant or transition economies. The dynamics of transitions between clusters are tracked, and recommendations are formulated for adaptive economic policy within the EU. The study proposes recommendations for a more targeted and differentiated policy framework aimed at fostering sustainable economic growth and innovation. The suggested measures include increasing R&D expenditure in less advanced countries, developing digital skills, improving infrastructure, and accelerating the transition toward a knowledge-based economy.*

**Key words:** digitalisation, economic growth, DESI, R&D, cluster analysis, European Union.

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*У статті здійснено порівняльний кластерний аналіз 27 країн ЄС за 2017 та 2022 роки на основі трьох ключових індикаторів: зростання ВВП на душу населення, індексу цифрової економіки та суспільства (DESI) та витрат на наукові дослідження й розробки (R&D). Обрані роки відображають економічну структуру до пандемії COVID-19 та її наслідки. Дослідження виявило наявність трьох стабільних кластерів: лідери цифровізації та інновацій, країни з високими темпами зростання, але низькою інноваційністю, а також група стагнруючих або перехідних економік. Встановлено, що попри підтримку з боку ЄС у вигляді структурних фондів та ініціатив цифрової трансформації, розриви між групами країн зберігаються. Деякі країни, наприклад, Ірландія чи Естонія, за п'ять років суттєво змінили позиції, тоді як інші, зокрема Португалія чи Словаччина, знизилися у рейтингу. Аналіз дозволяє простежити динаміку змін у кластерній структурі, виявити сталість розривів та оцінити ефективність політики ЄС у сфері цифрової та інноваційної конвергенції. Зроблено висновок, що структурні чинники, зокрема, якість освіти, інституційна спроможність та промислова база, залишаються головними детермінантами розбіжностей між країнами. Констатовано, що у період 2017–2022 роках у Європейському Союзі спостерігався поступовий прогрес, але не відбулося парадигмального зсуву в інноваційній та цифровій конвергенції. Початкова гіпотеза щодо зближення підтвердилася лише частково. Запропоновано рекомендації щодо більш цільової та диференційованої політики підтримки: підвищення витрат на R&D у країнах, що відстають, розвиток цифрових навичок, покращення інфраструктури, а також перехід до економіки, заснованої на знаннях. Висновок про те, що країни з вищим рівнем цифровізації та інноваційного розвитку також мають вищий рівень загального розвитку, є не просто спостереженням, а заклик до дії – посилити зусилля, щоб жодна держава-член не залишилася осторонь у цифрову та інноваційну епоху. Стаття є внеском у розуміння довготривалих тенденцій економічної дивергенції в ЄС та підґрунтям для вдосконалення політики зближення.*

**Ключові слова:** цифровізація, економічне зростання, DESI, R&D, кластерний аналіз, Європейський Союз.

**Problem statement.** The European Union has long aimed to foster economic convergence across its member states. However, persistent disparities in digitalisation, innovation, and economic resilience have challenged this vision. While structural funds and cohesion policies have provided support, disparities persist, particularly between high-income innovation leaders and emerging economies in Central and Eastern Europe.

The digital transformation and innovation capacity of EU member states are key drivers of economic growth and structural change. The European Union has aimed to foster economic convergence across its

member states. Digitalisation increasingly underpins economic performance – for example, recent studies find that “the EU’s economic growth is increasingly driven by digitalisation” (Doroiman & Sîrghi, 2024; Kolinets, 2017) [6; 9] – while investment in research and development (R&D) is unanimously considered one of the key drivers of sustainable economic growth. At the same time, substantial disparities remain across EU countries in technology adoption, innovation intensity, and per-capita income.

Understanding the evolving structure of economic development across EU member states is critical for designing effective and targeted policy interventions.

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This study builds on these approaches by performing cluster analyses of EU-27 countries using economic growth, digital index, and innovation (R&D) indicators for two snapshots (2017 and 2022). By comparing the resulting clusters, we aim to uncover how economic structure and digital/innovation profiles have evolved, and to draw implications for targeted policy support.

**Analysis of recent research and publications.** Digitalisation has emerged as a key driver of economic growth and competitiveness (Qu, 2017; Teng et al., 2022; Kolinets & Homotiuk, 2024) [13; 14; 10]. A growing literature emphasises that higher digital adoption tends to correspond with stronger economic performance. Bocean and Vărzaru (2023) show that “more digitised countries have a higher GDP,” though noting other factors also matter [3]. Similarly, Doroiman and Sîrghi (2024) report that EU economic growth in the post-pandemic period is strongly influenced by the digital transformation of businesses [6]. Their analysis of DESI scores and GDP metrics finds that different digital strategies yield varying growth outcomes, and highlights that “nuanced policy strategies” (e.g. enhancing digital skills, infrastructure, and supporting SMEs) are needed to realise the EU’s digital-decade goals.

Other studies, such as those of Vu et al. (2020) and Fernández-Portillo et al. (2020), demonstrate the significant role of digitalisation in fostering economic stability and growth [15]. However, the authors argue that the main focus should be changed from highlighting the positive link between digital technologies and growth to a deeper exploration of the mechanisms by which these technologies could influence economic performance.

Lobonț et al. (2025) find that EU countries with greater digitalisation (as measured by a composite digital index) tend to exhibit significantly higher economic development; their analysis of EU-27 data from 2017–2021 shows that countries ranking highly on digital intensity also enjoy elevated levels of GDP per capita [12]. These findings underscore that lagging behind in digital adoption can impede economic convergence. Indeed, Lobonț et al. (2025) note that pre-pandemic digitalisation levels in many member states were subpar, and they urge countries to “realign and reconfigure their digital transformation strategies” to accelerate growth through technology [12].

A robust body of recent literature reinforces the critical role of innovation and R&D in driving economic performance (Holt et al., 2021; Xu et al., 2020, Liu, 2022) [8; 16; 11]. R&D spending has long been seen as “one of the main driving forces of competitiveness and performance” in the EU economy. Recent research by Belanová et al. (2025) confirms a stable, significant relationship between R&D expenditure and innovation performance across EU countries,

but also notes that the efficiency of translating R&D into innovation outputs varies by country [2]. In other words, simply raising R&D spending is not a panacea – the innovation ecosystem and absorptive capacity also determine how effectively R&D investment contributes to actual innovation and growth outcomes. However, the unresolved question is whether EU economies exhibit convergence or divergence when growth, digitalisation, and R&D are examined jointly over time.

**Task statement.** The purpose of this paper is to examine the evolution of cluster structures over time and to identify which countries have improved or regressed in terms of digital performance, innovation investment, and growth dynamics. The findings aim to inform targeted EU policy instruments, including Horizon Europe, Digital Decade initiatives, and national smart specialisation strategies.

**Presentation of the main research material.** Cluster analysis as a method for grouping structurally similar economies has proven effective in comparative EU studies (Zabala-Iturriagoitia et al., 2020; Burian & Brčák, 2014) [17; 5]. Yet few studies compare clusters across time or evaluate shifts in cluster composition using recent data and updated DESI metrics. This approach helps simplify the complex multidimensional data into intelligible categories (e.g. “innovation leaders”, “moderate innovators”, “modest innovators” in the European Innovation Scoreboard (EIS) terminology).

Academic researchers have expanded on official assessments by using clustering techniques on a variety of indicator sets. Zaharia and Bălăcescu (2020), for example, clustered EU states according to DESI component indicators and confirmed clear digital disparities between the resulting groups [18].

This analysis focuses on the 27 EU member states (EU-27). We use data for two years: 2017 and 2022. These years were chosen to provide insight into the evolution of clusters over a five-year span marked by significant events and policy milestones. By 2017, the EU was nearing the end of the Europe 2020 strategy period and had seen several years of recovery from the sovereign debt crisis. In contrast, 2022 captures the initial aftermath of the COVID-19 pandemic (and related economic shock of 2020), as well as progress under the new Multiannual Financial Framework (2021–2027) and the NextGenerationEU recovery program. Comparing 2022 to 2017 thus enables us to observe structural changes and the impact of recent policy interventions (e.g. digital investments under national recovery plans) on countries’ positions.

We compiled a set of three key indicators for each country-year, reflecting economic performance, digital development, and innovation input, respectively:

GDP per capita growth (annual %) – the annual percentage growth rate of GDP per capita. This indicator represents recent economic performance

and convergence in income levels. We sourced this data from official statistics (Eurostat). Using 2017 and 2022 values captures the economic momentum in those years – notably, many countries in 2022 show a rebound growth spike following the pandemic-induced contraction of 2020.

Digital Economy and Society Index (DESI) – an index from 0 to 100 that summarises each country's performance on digital infrastructure, human capital (digital skills), integration of digital technology in business, and digital public services. We use the overall DESI score for the respective year. For 2017, the DESI value corresponds to the EU's 2017 digital scoreboard data; for 2022, we use the DESI 2022 report (which largely reflects data up to 2021). The DESI is a comprehensive measure of digitalisation and is directly comparable across countries.

Research & Development expenditure (R&D) as % of GDP – total gross domestic expenditure on R&D (GERD) expressed as a percentage of GDP. This indicator captures a country's innovation investment intensity. It reflects both public and private sector R&D efforts and is a key input into future innovation. Data for R&D (% GDP) were obtained from Eurostat for 2017 and 2022. R&D expenditure is also strongly correlated with a country's innovation performance as measured by composite indices like the EIS.

These three indicators were selected because together they provide a balanced representation of economic structure: GDP per capita growth indicates recent economic trajectory and catch-up potential; DESI reflects the degree of digital modernisation of the economy and society; and R&D intensity serves as a proxy for the innovation capacity and knowledge intensity of the economy. Clustering on this trio allows us to group countries that share not just similar outcome levels (growth) but also similar underlying development features (digital and innovation readiness). In essence, the approach recognises that in today's economies, digitalisation and innovation are intertwined with growth – high-growth economies often leverage technology and innovation, whereas those struggling to grow may be falling behind in those areas.

We conducted a cluster analysis for 2017 and for 2022 separately, using the above indicators for the EU-27 countries. Prior to clustering, the data for each year were standardised (z-scored) to ensure comparability between indicators on different scales. We employed a hierarchical clustering method with Ward's linkage and Euclidean distance, which is a common approach for country clustering analyses.

We settled on a 3-cluster solution for both 2017 and 2022. Three clusters offered a clear differentiation (high, medium, low innovation/digital groups) without over-fragmenting the sample. The results for 2017 are in Table 1 and Figure 1.

**Cluster 1: High-Innovation Economies (Innovation Leaders)** – This cluster consists of countries with high digitalisation and R&D investment, but relatively modest GDP growth in 2017. It includes nine countries: Austria, Belgium, Denmark, Finland, France, Germany, Luxembourg, the Netherlands, and Sweden. These nations were among the top performers in DESI (e.g. Denmark's DESI ~72, Sweden ~67 in 2017) and had R&D expenditures near or above the EU's 3% target (Sweden ~3.3% of GDP; Austria ~3.1%; others around 2.5–3%). As a group, Cluster 1's average R&D was about 2.6% of GDP and average DESI score ~61 (significantly above the EU average) – indicative of strong digital infrastructure, skills, and innovation ecosystems. Their annual GDP per capita growth in 2017 was moderate, averaging about 1.6%, which is lower than other clusters. This aligns with the idea that many of these countries are highly developed economies where growth tends to be steady but not explosive. The presence of France and Germany here (despite somewhat lower DESI scores than the Nordics) reflects their solid innovation input and large economies. In EIS terms, most of these were "Innovation Leaders" or strong innovators in 2017, and our cluster confirms they form a peer group.

**Cluster 2: Moderate Performers (Middle-tier Economies)** – The second cluster is the largest, containing 13 countries with mid-level DESI scores, low-to-moderate R&D, and moderate GDP growth. Members are Bulgaria, Croatia, Cyprus, the Czech Republic, Greece, Hungary, Italy, Latvia, Poland,

Table 1

The cluster profiles, 2017

Cluster	Country	GDP per capita growth (%)	DESI	R&D (% of GDP)
<b>0</b> – High Growth, Low R&D	Ireland, Romania, Malta, Lithuania, Estonia.	~7–9%	Medium	Low
<b>1</b> – Innovation Leaders	Netherlands, Luxembourg, Germany, France, Austria, Denmark, Belgium, Finland, Sweden	~1–2%	High	High
<b>2</b> – Transitional	Italy, Latvia, Czech Republic, Cyprus, Hungary, Bulgaria, Poland, Portugal, Greece, Slovakia, Slovenia, Spain, Croatia	~3–4.7%	Low–Medium	Low

Source: own calculations

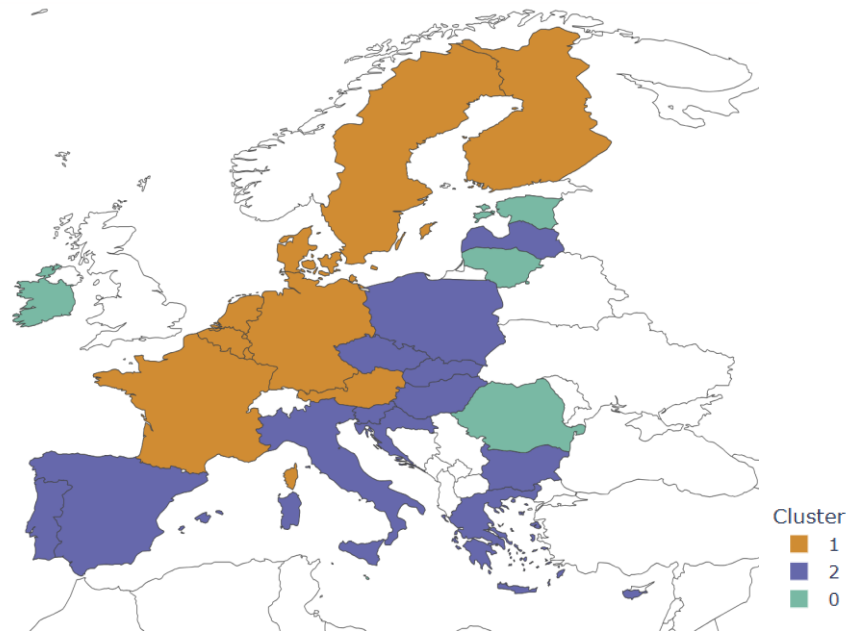


Fig. 1. Clusters of EU countries (2017)

Source: own calculations

Portugal, Slovakia, Slovenia, and Spain. This group is heterogeneous in geography (spanning Southern and Eastern Europe), but what they share is an intermediate status: their digital development in 2017 was behind the EU leaders (DESI around 40–55 range for most), and their R&D efforts were modest (cluster average ~1.1% of GDP, with most investing well under 2%). For instance, Italy and Spain invested about 1.2% in R&D in 2017, Portugal ~1.3%, while countries like Latvia, Croatia, and Bulgaria were below 1% – significantly under the EU average R&D of ~2.0% that year. GDP per capita growth in 2017 for this cluster averaged ~3.8%, higher than the high-innovation cluster. Several of these economies were in a catch-up growth phase (e.g. Eastern European members enjoyed robust growth in 2017, and countries like Spain and Portugal were rebounding post-Eurozone crisis). We can interpret Cluster 2 as “moderate innovators” or convergence economies – they were still catching up to the frontier in terms of digital and innovation indicators, but showing decent growth as part of that convergence process. This cluster aligns with the Moderate Innovators group in the EIS classification, which typically includes many of these countries.

Cluster 0: Emerging High-Growth Cluster – The third cluster in 2017 includes five countries characterised by low innovation inputs but very high economic growth rates. The members are Estonia, Ireland, Lithuania, Malta, and Romania. This is an interesting cluster that mixes a Baltic duo, a Mediterranean microstate, and Ireland and Romania – disparate geographies but a common thread: in 2017, each recorded exceptionally

high GDP per capita growth (cluster average ~7.3%, far above the others). Ireland’s growth was notably high (in part due to multinational-driven GDP quirks), Romania posted one of the EU’s highest growth rates (~8.8%), and Malta and Estonia were also well above 4–5%. However, in terms of DESI and R&D, these countries were intermediate to low. Ireland and Estonia had moderate DESI scores around the low 50s (Ireland’s digital performance was decent, though not yet at the very top in 2017), and Lithuania similar, whereas Romania lagged (~37.7 DESI). R&D spending in this cluster was relatively low: on average ~0.9% of GDP, with Romania especially low (~0.5% in 2017) and Malta ~0.6%, while Estonia was somewhat higher (~1.3%). We might label this group as “high-growth catching-up” economies or emerging innovators. Their booming GDP in 2017 suggests strong catch-up dynamics or special factors (Ireland’s case), but their innovation capacity had not yet caught up accordingly. This dichotomy raises a flag often discussed in literature: such countries risk the sustainability of growth if the high growth is not used to bolster digital and R&D foundations. Indeed, these countries were generally classified as either Moderate or Emerging innovators in EU reports, not yet in the top league despite fast economic expansion.

In summary, the 2017 clusters depict a familiar stratification in the EU: a leading group of highly digital, innovative economies with steady growth; a broad middle group of countries progressing but still behind the leaders in technology and innovation metrics; and a small group of fast-growing economies that were starting from a lower base in innovation

terms. Notably, no cluster in 2017 combined high innovation and high growth – the fastest-growing economies were not the most digitally advanced, and vice versa. This reflects the reality that some less-developed economies can grow quickly by capital accumulation or EU structural funds absorption, even if their digital/innovation metrics are lower. The policy implication at this point (2017) was that sustaining convergence would require those high-growth emergent countries to improve their innovation inputs, lest their growth slow once easy gains are exhausted.

Repeating the clustering with 2022 data reveals how the landscape evolved after five years (Table 2, Figure 2). The three clusters in 2022 show some continuity with the 2017 results (a high-innovation group is still clearly discernible, as is a lagging group), but also significant shifts in which countries fall into the lower vs. middle categories. It's important to recall that 2022 data reflect the post-COVID rebound – growth rates in 2022 were unusually high for some countries (a recovery effect), and DESI scores by then had generally improved across the

board (though our standardised clustering focuses on relative positions).

When we compare the 2022 clusters to those from 2017, we see some clear changes (Table 3, Appendix, Fig. A1, A2). The group of high-innovation countries got a bit smaller – France and Luxembourg are no longer in it. This shows that even well-developed countries can fall behind if others move ahead more quickly (Belanova, 2025) [2]. France's departure from the top group aligns with observed trends; despite improvements, France did not keep pace with the highest R&D growth or digital uptake of the Nordics and others, illustrating that sustained effort is needed to remain in the leader circle. Second, the middle tier in 2022 has a different composition: some countries like Estonia and Lithuania that were in the high-growth cluster of 2017 moved up to the intermediate cluster by 2022. This suggests they converted some of their growth into building digital and innovation capacity (the Baltics significantly improved in DESI rankings by 2022, particularly Estonia, which is now often cited as a digital government leader). Similarly, Cyprus and Latvia, which were previously in the moderate/low

Table 2

The cluster profiles, 2022

Cluster	Countries	GDP per capita growth (%)	DESI	R&D (% of GDP)
<b>Cluster 0</b> (Stagnating/Recovering Economies)	Slovenia, Slovakia, Luxembourg, the Czech Republic, Lithuania, Estonia, Latvia, Finland	-1.8 -2.7%	Medium	Low
<b>Cluster 1</b> (Innovation Leaders)	Austria, Netherlands, Germany, Ireland, Belgium, Sweden	1.6-3.8%	High	High
<b>Cluster 2</b> (High-Growth, Low-Innovation Economies)	Bulgaria, Croatia, Cyprus, Poland, Romania, Hungary, Greece, Portugal, Italy, Malta, France, Spain	4-10%	Low–Medium	Low

Source: own calculations

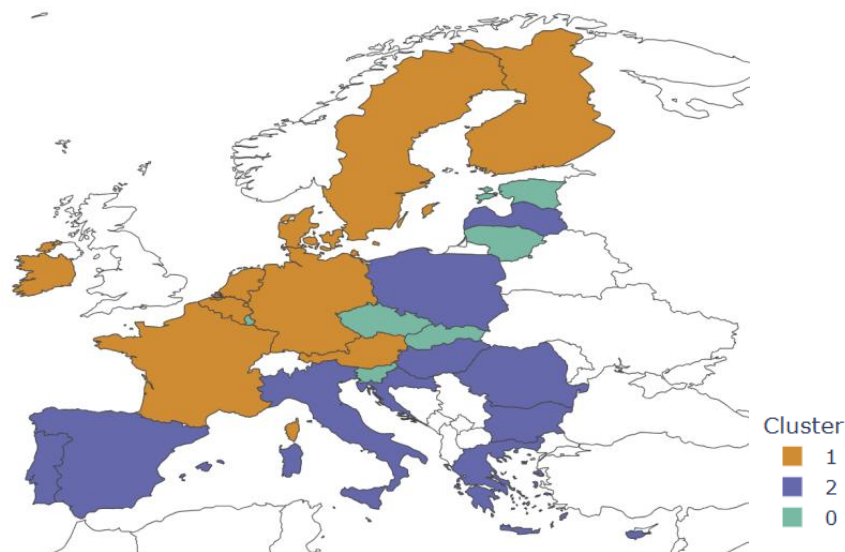


Fig. 2. Clusters of EU countries (2022)

Source: own calculations

group, are seen in the intermediate cluster – possibly reflecting specific advancements (Cyprus improved its digital connectivity and integration indicators).

On the other hand, Italy, Spain, Portugal, and Greece – which in 2017 were part of the moderate cluster – are found in 2022 among the lagging cluster. This indicates a relative regression: these Southern European economies, while improving in absolute terms, apparently did so at a slower rate than others, causing them to be grouped with the lower tier. In particular, their DESI and R&D trajectories have not been steep enough to keep them in the middle category, and they now sit alongside Eastern countries like Bulgaria and Romania in our clustering. This is an important finding: it underlines the persistent North–South digital divide, in addition to the oft-discussed West–East divide. By 2022, Eastern countries like Czechia, Slovenia, Estonia have in some aspects caught up or even surpassed some Southern states in digital and innovation metrics, moving into the middle or higher cluster, whereas Italy and others remain laggards in those dimensions. This is consistent with analyses that find some Central-Eastern European states (the Visegrád and Baltics) rapidly improving their digital infrastructure and innovation frameworks, sometimes overtaking parts of Southern Europe in relative terms (Bálint & Barta, 2024) [1].

Another striking change is the position of Ireland. In 2017, Ireland was grouped with high-growth emerging economies. By 2022, Ireland appears in Cluster 1. It moved to balanced growth + strong R&D/DESI. This does not mean Ireland regressed in absolute terms – on the contrary, Ireland’s digital indicators improved and it continues to have a strong high-tech sector. However, its R&D spend relative to GDP is around 1.2% (2019 figure) to 1.6% (2022 est.), which is surprisingly not high given its per capita income (partly because its GDP is inflated by foreign company profits). Its DESI, while above EU average, is not top-tier (Ireland has strengths in

integration of technology and digital public services, but weaknesses in digital skills among the general population, for example). Hence, in a cluster analysis that equally weights R&D and DESI, Ireland aligns more with countries like Malta or Spain (moderate DESI, moderate R&D) than with the true innovation leaders. Ireland’s phenomenal GDP growth (double-digit in 2022) places it with the high-growth cluster, but since that cluster also happens to be the low innovation one, Ireland lands there. This again shows that GDP growth alone is a misleading indicator of development – Ireland’s growth is driven by idiosyncratic factors, and the clustering rightly points out its innovation input gap relative to its output. Policymakers in Ireland acknowledge this and have been increasing R&D support, but the data suggest more effort is needed to match the innovation capacity of similarly advanced economies.

Overall, the stability vs. change in clusters from 2017 to 2022 aligns with findings in the literature that most countries tend to stay in their relative band, but a few can shift given the right conditions (Bálint & Barta, 2024) [1]. In our results, most of the 2017 top-cluster countries remained top in 2022 (with minor exceptions), and most bottom-cluster countries remained bottom (with the composition only changing by inclusion of some Southern states). The middle saw more reshuffling, which is expected, as that’s where countries on the cusp can move up or down. These results also mirror the European Innovation Scoreboard observations that highlight stability in performance groups, with only occasional moves (e.g. Hungary’s improvement, France’s slip as noted) (Belanova, 2025) [2].

To put these results in perspective: by 2022, we effectively see an EU divided into (i) an Innovation/Digital Leader cluster – highly developed knowledge economies with strong innovation systems but currently slower growth; (ii) an Intermediate cluster – a mix of advanced and converging economies that have

Table 3

Countries That Changed Clusters (2017, 2022)

Country	Cluster 2017	Cluster 2022	Change Description
<b>Czech Republic</b>	2 (Transitional)	0 (Stagnating)	Slower growth and stable DESI/R&D moved it into a lower-performance group.
<b>Ireland</b>	0 (High Growth)	1 (Innovation Leaders)	Moved from catch-up growth to balanced growth + strong R&D/DESI.
<b>Luxembourg</b>	1 (Innovation)	0 (Stagnating)	Growth slowdown outweighed high R&D, pushing it into a lower cluster.
<b>Malta</b>	0 (High Growth)	2 (High Growth, Low Innovation)	Stayed growth-focused but lagged in innovation and DESI.
<b>Romania</b>	0 (High Growth)	2 (Same Cluster Type)	Remained growth-driven but lower R&D
<b>Slovakia</b>	2 (Transitional)	0 (Stagnating)	Lack of progress in digital/innovation with slower growth.
<b>Slovenia</b>	2 (Transitional)	0 (Stagnating)	Similar stagnation trend as Slovakia and the Czech Republic.

Source: own calculations

medium performance in innovation and digitalization and varied growth outcomes; and (iii) a Catch-up cluster – countries lagging in innovation and digital foundations but experiencing short-term high growth as they recover or converge economically. The fact that these clusters remain over time shows that basic differences between countries – like their education systems, institutions, and industries – still matter. Although EU policies such as structural funds, the Digital Agenda, and innovation programs help, they have not yet managed to remove these long-lasting gaps. This resonates with Borowiecki et al. (2021)'s conclusion that digital convergence remains an “open problem,” requiring intensified and tailored policy actions [4].

**Conclusion.** This study set out to analyse and compare the clustering of EU member states in 2017 and 2022 based on key indicators of economic performance (GDP per capita growth), digital development (DESI), and innovation effort (R&D spending). Our findings reveal a consistent core-periphery pattern in Europe's innovation and digital landscape, with only limited signs of convergence over the five-year period. The high-innovation cluster (largely comprising Northern and some Western European countries) maintained its lead from 2017 to 2022, continuing to invest heavily in R&D and reap the benefits of advanced digital infrastructure. By contrast, a group of lagging countries – including several Southern and Eastern European economies – remains characterised by low R&D investment and below-average digital indicators. Some of these laggards enjoyed strong economic growth in 2021–2022, but this appears to be a rebound effect rather than a sign of fundamental improvement in innovative capacity. Meanwhile, an intermediate group of countries occupies the middle ground, with moderate progress in digitalisation and innovation; a few climbed upwards (e.g. the Baltic states), and a few slipped downwards (notably France, a slight relative decline, and Italy/Spain falling behind faster-improving peers).

These results carry important policy implications. First, they underscore that achieving EU-wide convergence in innovation and digital development is a slow process – one that current policies have only partially succeeded in accelerating. The enduring gaps call for renewed and more tailored policy interventions. Countries in the lagging cluster (many of which are in Eastern and Southern Europe) clearly need continued support to build their innovation ecosystems: this includes boosting R&D investment (both public and private), improving research infrastructure, and fostering higher education and skills. The fact that R&D expenditures in these countries remain around 1% of GDP or less, versus ~3% in the leaders, is a stark disparity. Policy measures could involve strengthening linkages between academia and

industry, enhancing absorption capacity for innovation (especially in SMEs).

Second, the persistent digital divide highlighted by our DESI-based clustering suggests that EU digital policy initiatives (such as the Digital Decade targets) must continue with vigour. There is evidence that common EU frameworks (e.g. cross-national funding for broadband, digital skills programs) have helped all countries improve their DESI scores, but the lower-tier countries often started far behind and are not catching up fast enough. Policy implications here include concentrating resources on the specific weaknesses of lagging countries – for example, digital skills training in the workforce for countries where human capital is the bottleneck, or accelerated deployment of broadband and 5G in regions lacking connectivity. The Recovery and Resilience Facility (RRF) has been a positive step, mandating a minimum 20% of funds go to digitalisation; in practice, countries on average allocated ~26% to digital investments. Effective use of these funds is crucial. Our findings suggest that some countries (like Italy, Greece, Poland) that are in the lagging cluster have indeed earmarked sizable RRF resources for digital and innovation – the success of these investments will determine if they can climb out of the low-innovation trap in the coming years.

Third, the analysis hints at structural economic differences underlying the clusters. The innovation leaders cluster largely consists of knowledge-intensive economies with strong institutions and often a high share of high-tech industries (e.g. machinery, ICT, advanced services). In contrast, many laggards have traditionally relied on lower-tech industries, tourism, or assembly-type manufacturing, and in the case of some Eastern countries, on lower labour costs to attract investment. As those advantages erode, there is a pressing need for these economies to upgrade their structure towards more knowledge-intensive activities. Our results reinforce this point: for example, countries like Hungary and Poland, which have grown through manufacturing integration into EU value chains, still show low R&D and digital scores, indicating they are often not hosting the R&D-intensive parts of those value chains. Without policy intervention, they risk being stuck in the middle-income status. Shifting to a higher value-added economic structure will require focusing on innovation policy – supporting startups, attracting R&D investment, improving governance – so that these countries can develop indigenous innovation capabilities rather than only relying on external technology.

From a broader perspective, our comparative clustering underscores that “one-size-fits-all” policies are suboptimal when countries are at different development stages. Each cluster of countries may benefit from differentiated policy approaches. For the lagging cluster, basic infrastructure and

skill-building is priority; for the intermediate cluster, incentives for higher R&D and transitioning to more complex economic activities are needed; and for the leader cluster, frontier innovation and sustaining high productivity are the focus (along with ensuring inclusivity, as these societies are highly developed).

In conclusion, the period 2017–2022 saw incremental progress but not a paradigm shift in Europe's innovation and digital convergence. The initial hypothesis of convergence is only weakly supported. Our study contributes to the evidence base by highlighting these persistent divides through a multi-indicator cluster lens. The years ahead – with the implementation of the Digital Decade roadmap and massive EU investments in green and digital transitions – will be critical. If the policy implications drawn above are acted upon, we would hope to see more countries moving into higher clusters in the future, indicating a narrowing of Europe's innovation gap. Ultimately, achieving a more cohesive economic structure across the EU, where prosperity is shared and not concentrated, will depend on how effectively lower-performing countries can adopt the best practices of the leaders in boosting R&D, fostering digital skills, and embracing innovation-driven growth. The insight that “countries with higher digitalisation and innovation also enjoy higher development” is not just an observation, but a call to action: to intensify efforts so that no member state is left behind in the digital and innovation age.

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