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THE DIGITAL DIVIDE IN THE VISEGRAD COUNTRIES - INSIGHTS FROM A COMPARATIVE ANALYSIS

Katarzyna Żmija
Krakow University of Economics, Krakow, Poland
E-mail: zmijak@uek.krakow.pl
ORCID 0000-0002-4119-8012

Wahida Ahmad
Arshad Ayub Graduate Business School,
Universiti Teknologi MARA, Shah Alam, Malaysia
E-mail: wahida@uitm.edu.my
ORCID 0000-0002-8874-8229

Wojciech Szymla
Krakow University of Economics, Krakow, Poland
E-mail: szymlaw@uek.krakow.pl
ORCID 0000-0003-4580-9084

Marcin Suder
AGH University of Krakow, Krakow, Poland
E-mail: msuder@agh.edu.pl
ORCID 0000-0001-6279-7359

Gagan Deep Sharma
Széchenyi István University, Győr, Hungary;
AGH University of Krakow, Poland;
Guru Gobind Singh Indraprastha University, Sector 16C, Dwarka, New Delhi, India
Email: angrishgagan@gmail.com
ORCID: 0000-0001-5379-0761

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ABSTRACT. The Visegrad Group, comprised of the Czech Republic, Hungary, Poland and Slovakia, provides a compelling case of digital transformation. These countries, with similar historical and socioeconomic backgrounds, are working to overcome the digital divide, recognizing its role in future economic growth. This paper analyzes and assesses the digital divide between the Visegrad countries and the remaining EU member states during the period 2017-2022. A comparative analysis was carried out based on Eurostat DESI statistics and its four sub-indices. To uncover major similarities and contrasts, the Ward method was used. Our findings demonstrate significant disparities in access, skills, and usage between V4 and other EU states, reflecting the strengths and weaknesses of each country's digital development. We identify key similarities and contrasts within the V4 before and during the pandemic. Results reveal substantial heterogeneity across the V4, with varying performance across the four dimensions of digitalization. Consequently, the V4 cannot be considered a homogenous bloc, as digital inequalities persist, particularly concerning access, skills and ICT usage. Both narrowing and widening of the digital divide occurred, depending on the country and dimension. Even in areas of improvement, substantial room for further development remains.

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Introduction

Digitalization offers numerous benefits, however it has also brought to light significant negative consequences, referred to as the "digital divide," "digital gap," "digital inequalities," or "digital exclusion" (Van Dijk, 2020, Helsper, 2021, Damiani & Rodríguez-Modroño, 2024). Regardless of the terminology used, this complex issue means excluding individuals, groups, and communities from the advantages of digital technologies (Robinson et al., 2020). The COVID-19 pandemic sharply exacerbated these pre-existing disparities, particularly impacting vulnerable populations with limited access to Internet and skills in using digital technologies (Kuc-Czarnecka, 2020). The pandemic underscored the critical role of the digital divide in deepening social and economic inequalities (Ali & Faroque, 2023).

The European Union actively pursues a range of public policies, strategies, and programs to leverage the potential of digital transformation while mitigating its challenges (European Commission, 2022a). Achieving digital goals necessitates a significant acceleration and intensification of member states' efforts to not only advance digitalization but also bridge the digital divide within the EU and enhance global competitiveness. The I-DESI analysis based on 2015-2018 datasets revealed significant disparities in digital performance across EU member states: while the top performers surpassed leading economies like the United States, United Kingdom, Canada, and Japan, the bottom-ranking countries lagged behind Chile, Russia, China, and Serbia (Lomba et al., 2022). Moreover, annual European Commission's DESI reports consistently emphasize that substantial disparities still persist among member states (European Commission, 2022b).

While numerous studies have examined digital development asymmetries within the European Union (Borowiecki et al., 2021, Kolupaieva & Tiesheva, 2023, Pinto et al., 2023), in Central and Eastern European countries (Tőkés, 2022), and in individual member states (Kuc-Czarnecka, 2020, Benediktová et al., 2023), there are little up-to-date studies that provide insights into the digital divide within the Visegrad Group. Over the past three decades, driven by political and economic reforms and EU integration, the Visegrad Group (V4) countries – the Czech Republic, Hungary, Poland, and Slovakia – have undergone rapid socioeconomic modernization, including significant digitalization (Vallušová et al., 2022). This digital transformation is particularly noteworthy, reflecting these countries' endeavors to bridge the digital divide with the more digitally advanced "Old Union" countries, a crucial step for their future economic growth. For this reason this study aims to analyze and assess the digital divide between the Visegrad countries (V4) and the remaining 27 EU member states during the period 2017-2022. To achieve this, we will address the following research questions:

- What were the digitalization achievements of the V4 countries from 2017 to 2022?
- How did these achievements compare to other EU countries, and what is the extent of the digital divide?
- Did the digital divide narrow or widen during this period, particularly considering the pre-pandemic (2017-2019) and pandemic (2019-2022) periods?
- To what extent did the V4 countries exhibit similarities and differences in the pace and direction of changes in their digital divide during these sub-periods?

This study offers two primary contributions. Firstly, it not only quantifies and assesses the extent of the digital divide within the V4 but also provides a deeper understanding of its unique characteristics within this context. By comparing V4 performance to that of the EU as a whole, the study reveals the scope of the digital divide at various levels and highlights both similarities and differences among the V4 countries. This analysis also informs future research directions. Secondly, by evaluating the outcomes of digitalization efforts within the V4, the study identifies key factors contributing to the observed digital divide. This knowledge can be instrumental in developing more effective and coherent policy frameworks to address the digital divide and mitigate digital inequalities within the V4 countries.

To achieve these objectives, this paper is structured as follows. Section 2 presents a literature review on the digital divide, including challenges in its measurement and existing research on the V4 countries. Section outlines the research methodology employed in this study. Section 4 presents the results of comparative analyses, utilizing time-series analysis and cluster analysis. Section 5 presents the discussion of findings. Finally, section 6 provides concluding remarks, acknowledges study limitations, and offers recommendations for future research.

To fulfil the study's objective, a comparative analysis was conducted between the Visegrad countries and the remaining EU member states, utilizing publicly available Eurostat data on the Digital Economy and Society Index (DESI) and its four sub-indices. Furthermore, the Ward method was employed to identify key similarities and differences in the digital divide among these countries.

1. Literature review

1.1. Digital divide - from Internet access to ICT use outcomes

Existing literature highlights the digital divide as a complex, dynamic, and multifaceted phenomenon, encompassing a set of various divides and driven by numerous factors (Vassilakopoulou & Hustad, 2021; Aissaoui, 2022). Recognizing this complexity, numerous studies in recent decades have focused on identifying, measuring, and understanding these existing disparities. Researchers commonly utilize a three-level framework to analyze this phenomenon.

Initially, the digital divide was primarily understood as a binary distinction between those with and without internet access (van Dijk, 2005, Scheerder et al., 2017). This "access divide" was extensively studied from the early 90s, but its limitations became evident over time (van Dijk, 2020). Subsequent research shifted focus towards understanding the underlying reasons for disparities in access and usage of ICT (Cruz-Jesus et al., 2012). Consequently, in recent years relatively little research has examined the first level digital divide. However, the COVID-19 pandemic highlighted the continued significance of access to ICT as a critical issue in many parts of the world (Lai & Widmar, 2021; Mishchuk et al., 2023). Moreover, as broadband internet access and digital devices have become more widespread, the focus has shifted to encompass factors beyond basic access, including the availability of cutting-edge technologies, reliable high-speed internet connections, and the affordability of internet services (Lutz, 2019, Reddick et al., 2024).

Scholars of the second level digital divide claimed that even with universal physical access the divide continues to expand due to diverse modes of use within the group of users of digital devices, which can be attributed to different levels of digital competence (Hargittai & Hinnant, 2008; Mishchuk et al., 2025; Schmoelz, 2023). This perspective shifted the focus towards examining factors such as inequalities in technical means, autonomy of use, usage patterns, and digital skills (Lythreatis et al., 2022). Research within the second-level divide

focuses therefore on two main strands referring to inequalities among Internet users belonging to different social groups in the way they use ICT and digital skills as one of the most important factors in conceptualizing the second level digital divide (Aissaoui, 2022). The COVID-19 pandemic underscored the critical importance of digital skills in navigating existing inequalities and the urgent need for acquiring new digital competencies. Furthermore, the emergence of new technologies like artificial intelligence, big data, and data mining necessitates the development of new skills, thus shaping the future direction of research on the second-level digital divide (Lutz, 2019, Cotter & Reisdorf, 2020).

Recent discourse on the digital divide has expanded to encompass the beneficial outcomes of internet use, a concept termed the "third-level digital divide" (Wei et al., 2012). Scholars argue that even with equal access and skills, individuals may not equally benefit from internet usage (van Deursen et al., 2016; Ragnedda, 2016). Two primary approaches investigate this third-level divide. The first one examines the relationships between various second-level digital divide factors and offline outcomes (Van Deursen & Helsper, 2015; Scheerder, et al., 2017). The second approach applies the theory of capital to understand the digital divide in terms of economic, social, and cultural capital and to demonstrate its relevance in the digital domain (Merisalo & Makkonen, 2022; Park & Chun, 2024). This concern is echoed in critical smart-city scholarship, which cautions that digitalisation initiatives risk reinforcing existing socio-digital inequalities unless residents' digital literacy, agency, and equitable access to digitally mediated public infrastructure are explicitly addressed by design, rather than assumed to follow automatically from expanded connectivity or e-government provision (Ylipulli et al., 2025).

Since current understandings of the digital divide may be inadequate to fully explain and address the evolving forms and consequences of emerging inequalities, scholars propose new perspectives on the existing three-level framework (Lythreatis et al., 2022, Kovač et al, 2024) and postulate the introduction of further levels (Gran et al., 2021; Cinnamon, 2020; Schmölz et al., 2020, van de Werfhorst et al., 2022).

Given the strong socio-demographic and economic underpinnings of digital divide, a significant body of research focuses on understanding these inequalities among individuals and socioeconomic groups. Alongside this, geographical context plays a crucial role. In the spatial context the digital divide is basically considered at two levels. At the international level, the digital divide manifests as disparities between countries. At the domestic level, it reflects inequalities within individual countries. However, there are also other geography-related divides considered: among the developed countries, between the developed and developing countries, between the regions, as well as between the rural and urban areas (Aissaoui, 2022). Regardless of the specific geographical context, these digital disparities can arise in various forms, including differences in access to ICT, digital skills, usage patterns, and the outcomes of ICT usage, all of which are often rooted in distinct economic, social, political, or technological conditions.

1.2. Measuring the digital divide

Research conducted for at least two decades has shown that digital divide requires a diverse approach to its measurement (Barzilai-Nahon, 2006; Barzilai-Nahon et al., 2012; Korovkin et al., 2022; Mahdiloo et al., 2023). The primary source of data for analysis is data from official national statistics, collected and processed by organizations such as the ITU (International Telecommunication Union - UN agency), Eurostat, World Bank, OECD and many others, as well as independent surveys. The official statistics collect more and more detailed data on the state of digitization in various aspects and in various breakdowns every

year. For example, the ITU tracks 178 digitization indicators with additional breakdowns, and Eurostat compiles 105 indicators within its Digital Economy and Society database.

Some organizations, individual researchers, or research teams propose a series of indexes for general purposes or to obtain more accurate results of their own research to allow a synthetic assessment of the degree of digitization in different areas using one or more indicators. Examples of such synthetic indices includes: The Digitization Index (DiGiX), Digital Economy and Society Index (DESI), ASEAN Digital Integration Index (ADII), Digital Intelligence Index (DII), World Digital Competitiveness (WDC), etc.. These indices exhibit significant variation in their construction methodologies, underlying metrics, and coverage scope. Choczyńska et al. (2024) provide an analysis of selected indices. Attempts are also made to create indices based on those already existing but requiring a smaller number of indicators while maintaining comparable results – for example, in the case of the DESI index (Bruno et al., 2023). Furthermore, specialized indices, including the E-Government Development Index (EGDI), E-Participation Index, Human Capital Index, and Digital Readiness Index, have been developed for assessments within narrower domains of digitization.

To assess the digital divide, researchers analyze temporal trends in individual indicators and composite indices, comparing their values across global, national, and regional contexts. Statistical methods employed include concentration and regression analyses, including the Gini coefficient analysis (Riccardini & Facio, 2002). Clustering techniques are widely utilized to group entities with similar characteristics based on individual or grouped indicators (Cruz-Jesus et al., 2012, Borowiecki et al., 2021, Kolupaieva & Tiesheva, 2023). A special index has also been created to study the digital divide in detail. The Digital Divide Index (DDI) is composed of two scores: the infrastructure/adoption (INFA) score and the socioeconomic (SE) score (Gallardo, 2024).

A comprehensive analysis of digital divide measurement methods is conducted by Barzilai-Nahon (Barzilai-Nahon, 2006). She examined and compared both the methodology of measuring indicators and assessed the synthetic indices used so far. A similar analysis was conducted by Vehovar et al. (Vehovar et al., 2006), who reached a rather controversial conclusion that the measurement methods used may lead to different results and conclusions.

The digital divide has been extensively researched within the European Union in recent decades, utilizing various methodologies (Borowiecki et al., 2021, Małkowska et al., 2021, Castillo-Tellez, 2023). The Digital Economy and Society Index (DESI), a prominent index for EU countries, leverages official Member State statistics to monitor progress in digital transformation and address the digital divide. Since 2014, the European Commission has annually published digitization reports based on DESI. Furthermore, digital divide measurements are made for the internal needs of countries, to illustrate differences in groups of individuals, households and enterprises (Lucendo-Monedero et al., 2019).

Research findings on the digital divide inform the development of local, regional, national, and EU policies (Decision 2022/2481; European Commission, 2023) aimed at mitigating digital exclusion, particularly for vulnerable social groups (de Clercq et al., 2023). This research enhances our understanding of the digital divide, enabling the identification of its scale, the root causes of inequalities within individual countries (Tutar et al., 2025; Várallyai et al., 2015), the effectiveness of policies in digital transformation (Drăgan et al., 2024; Yarovenko et al., 2025) and digital divide mitigation across various domains, such as e-government (Pérez-Morote et al., 2020; Ravšelj et al., 2026) or e-education (Cruz-Jesus et al., 2016; Staniec et al., 2023).

1.3. Digitalization and the digital divide in the V4 countries

The process of digital transformation and the digital divide in the Visegrad countries have been a field of research for several years, primarily driven by scholars from these countries. The research problem appeared both in the perspective of the CEE countries, the V4 group and its individual member states.

A particularly insightful area of comparison involves research conducted prior to EU accession. Research conducted in 2003-2005 in Hungary (Kiss, 2007) revealed a significant digital gap, highlighting its emergence even then. The author examines Hungary's accomplishments in digital equity, exploring new ways to bridge the digital divide and address issues of traditional social exclusion in the information society. Research conducted in the following years (2005-2008) in the Czech Republic further confirmed the significance of this problem (Lupáč, Sládek, 2008). The study identified several key challenges: the lack of public access points or awareness of them, lack of digital skills, and low understanding of the benefits and possibilities of the internet. The analysis revealed a stark demographic disparity in physical internet access, with older individuals, those with lower education levels and incomes, and those with limited social networks significantly lagging behind in the process of informatization. Furthermore, the research indicated a widening of this digital divide. However, research conducted in Hungary in 2013 revealed a significant improvement in internet access, suggesting a considerable reduction in the digital divide. At the same time, the authors point to the positive impact of European Union funding in reducing this problem. However, the study highlighted the persistent challenges of the rural-urban divide and the exclusion of elderly individuals (Várallyai et al., 2015). Subsequent research in Poland (Adamczyk & Betlej, 2021; Tomczyk et al., 2023) further emphasized the ongoing exclusion of older adults. From the point of view of analysing the causes and possibilities of narrowing the digital divide, an important role is played by studies analysing the digital transformation policies of each V4 country, examining their objectives and implementation outcomes (Drăgan et al., 2024; Török 2024). Evidence from Ukraine's transport-sector reconstruction illustrates a parallel dynamic outside the EU context: regulatory fragmentation and chronic underinvestment in digitalisation constrain infrastructure modernisation, whereas alignment with EU regulatory standards and targeted technology investment accelerate digital catch-up, underscoring that institutional harmonisation – not connectivity alone – is often the binding constraint on narrowing a digital divide (Vovk et al., 2025).

Taking into account the purpose of this paper, comparative studies are crucial. These studies assess the performance of individual V4 countries relative to other EU countries or global leaders in digitalization, providing valuable insights into the specific factors and barriers to digitalization within each country. In recent years, comparative studies have been conducted on the level of digitalization in Hungary (Cseh-Zelina, 2023), Poland (Stolarczyk, 2018; Ćwiek, 2018), and Slovakia (Jenčová et al., 2023). A key feature of these studies is the extensive utilization of the DESI Index, enabling direct comparisons of findings across countries.

Key research benchmarks include studies directly examining digitalization, digital transformation, and the digital divide within the V4 countries and in comparison, to the broader EU context. Such research has been conducted in recent years by Chetverikova (2023). In this paper, she identifies strengths and weaknesses of digital development of the Visegrad countries that predetermined their “lagging” position. Chetverikova (2023) identifies the strengths and weaknesses of V4 countries' digital development, explaining their "lagging" position. Vallušová et al. (2022) attribute a significant portion of this lag to human capital deficiencies, including lower-than-EU-average digital skills and pronounced digital inequalities. Esses et al. (2021) examine the interplay of digitalization and sustainability, also utilizing DESI indicators.

Kuráková et al. (2021) employ the Digital Divide Index, offering a distinct perspective on digital disparities compared to DESI-based analyses. This skills-related constraint is corroborated by firm-level evidence from Slovakia, where the national DESI integration level is described as only moderate and the shortage of digitally skilled labour – rather than financing – is identified as the more critical barrier to Industry 4.0 adoption among SMEs, reinforcing the centrality of the Human Capital dimension in explaining V4 countries' persistent digital lag (Nagy, 2025).

Mészáros (2024) emphasizes the critical link between digitalization and enterprise efficiency, comparing three V4 countries to digitalization leaders (Finland, Denmark, and the Netherlands). Čerňanová & Stovíček (2024) analyze digital competitiveness in V4 countries (2018-2022) using the IMD index, which assesses knowledge, technology, and future readiness. They underscore the crucial role of bridging the digital divide in enhancing national competitiveness. An even longer research period was adopted by Ragnedda & Kreitem (2018) who examined the digital divide in 11 former Eastern Bloc countries (2007-2018), identifying three distinct levels of the divide and comparing countries to the EU28 average. Overall, existing research highlights the persistent presence of a significant digital divide within the V4 countries, while also acknowledging disparities in the scale of this divide and the pace of digital transformation across these countries.

2. Research methods

To provide a comprehensive overview of the digital divide across the Visegrad countries, we analyzed data from the Digital Economy and Society Index (DESI) and its four sub-indices. This analysis aimed to track changes in the digital divide within the V4 countries over time in comparison to other European Union countries and to identify similarities and differences regarding changes in this phenomenon at its different levels. The analysis utilized data from 2017 to 2022, encompassing all 27 EU member states. The data source was the Eurostat database (Kowalik et al., 2024).

The DESI employs a three-level structure, encompassing dimensions, sub-dimensions, and individual indicators. Our analysis focused on the DESI and its four main dimensions (sub-indices): Human Capital (HC), Connectivity (Conn), Integration of Digital Technology (IoDT) and Digital Public Services (DPS), that collectively constitute the overall DESI index. The DESI score is calculated as a weighted sum with weights associated with each dimension, sub-dimension, and indicator. Notably, each of the four analyzed sub-indices carries an equal weight of 25% (European Commission, 2022c).

The selection of the DESI index was driven by the research objectives and several key considerations. The DESI indicators provide a multifaceted perspective on the digital divide by encompassing various factors that influence the level of digitalization, as identified in the literature. Consequently, the DESI can effectively measure the digital divide of the first level (access/capacity/affordability) and second level (Internet user skills, advanced skills and development, ICT usage in business and public sector). However, the DESI does not assess the third-level divide, which pertains to the offline impacts of ICT within a country. Furthermore, the EU's unified statistical system and standardized data collection and calculation processes across all member states contribute to the harmonization and reliability of this data for our research objectives. The utility of the DESI for assessing the digital divide is further supported by the findings of other researchers (Laitsou et al., 2020, Borowiecki et al., 2021, Olczyk & Kuc-Czarnecka, 2022, Bruno et al., 2023). Recent machine-learning-based analysis of the full 85-indicator DESI dataset for 27 EU countries (2017–2022) confirms that digital competence and business innovation exert by far the strongest positive influence on GDP per capita, while

individual digital-development components function largely independently of one another and generate economic returns only when supported by adequate institutional capacity – a finding directly relevant to interpreting why V4 countries' gains in isolated DESI dimensions have not uniformly translated into a narrower overall digital divide (Yarovenko et al., 2025).

This research employed a multifaceted approach to data analysis. Data on the DESI index and its four sub-indices were utilized, incorporating descriptive statistics and basic measures of time series dynamics, i.e., absolute annual increment. This analysis enabled determining the level of digitalization within the V4 countries, tracking the dynamics of changes in index values over time, assessing the scale and pace of change in the digital divide and identifying the specific dimensions within which the digital divide manifested. The data descriptions include several comparative breakdowns: a general description of the data for Visegrad countries, yearly trend analysis and a comparison with the EU27 and Finland, which had the highest DESI score in any of the marginal years of analysis.

To classify countries in terms of the similarity of changes in the value and structure of the DESI index, a cluster analysis was used (Everitt et al., 2001). Our research uses the most widespread hierarchical clustering method – the Ward method, which takes a variance analysis approach to estimate the ditance between the focus (Murtagh & Legendre, 2014). This method aims to minimize the sum of squared deviations of any two clusters that can be formed at any stage of the algorithm (Ward, 1963). The applied method is considered one of the best methods of cluster analysis, due to its effectiveness in reproducing the real structure of data and creating clusters of similar numbers. However, it aims to form clusters of relatively small size. The principle of this method is not optimization, but minimization of heterogeneity (Majerova & Nevima, 2017). For this reason it aims to find the greatest similarity between objects, what was important from the point of view of objectives of our study. No significant linear relationships between the different variables were found for the data considered. The selection of the number of clusters was based on the difference between the maximum similarity within the groups and the minimum (Kaufmann & Rousseeuw, 1990). On this basis, an optimal number of concentrations of four was established. Cluster analysis was carried out with the use of the Statgraphics 18 program. Figures were prepared with the use of Excel.

Our analysis covered the years 2017 – 2022. Given the significant impact of the COVID-19 pandemic on digitalization efforts across countries, we divided this period into two sub-periods: 2017-2019 (pre-pandemic) and 2019-2022 (pandemic). This approach allowed for capturing the average annual pace of changes in individual EU countries, including the V4 countries, and their specificity in these two distinguished sub-periods.

3. Results

3.1. Digital performance of Visegrad countries in the years 2017-2022

The data for the years 2017-2022 suggest major improvements in overall digitalization (measured by DESI), as well as Human Capital, Connectivity, Integration of Digital Technology and Digital Public Services for individual countries, the EU27 and the Visegrad countries. Notably, Finland outperformed in analyzed years, being among the leaders in business digitalization, skilled workforce and comprehensive digital public services. DESI scores varied among the Visegrad (V4) countries between 2017 and 2022. Three of the four countries – Poland, Hungary, and Slovakia – consistently were in the bottom of the ranking of all EU member states in terms of DESI performance (*Table 1*). All V4 countries exhibited results below the EU average of 33.7 in 2017 and 52.3 in 2022. Poland consistently recorded the lowest scores, improving from 24.9 in 2017 to 40.6 in 2022. In contrast, the Czech Republic

achieved the highest DESI scores among the V4 countries and showed the closest proximity to the EU average, increasing from 31.8 in 2017 to 49.1 in 2022. Hungary and Slovakia displayed comparable DESI scores throughout the analyzed period (28.3 and 29.8 in 2017 and 43.8 and 43.4 in 2022, respectively).

Table 1. The values of DESI and its four sub-indices in the years 2017, 2019, 2022 in EU27 and V4 countries

Index	Year	Min	Max	EU-27	Czechia	Hungary	Poland	Slovakia
DESI	2017	19.40	47.85	33.72	31.83	28.26	24.93	29.78
	2019	22.36	54.14	38.64	37.19	32.18	29.78	33.25
	2022	30.58	69.59	52.28	49.14	43.76	40.55	43.45
HC	2017	6.97	16.16	10.38	10.17	9.11	8.05	9.40
	2019	6.99	16.44	10.71	10.74	9.11	8.48	10.00
	2022	7.73	17.85	11.44	11.40	9.61	9.26	11.03
Conn	2017	3.16	9.86	6.19	5.60	6.41	5.13	6.51
	2019	1.07	10.97	7.65	7.30	7.91	6.59	6.94
	2022	9.96	19.27	14.98	13.17	14.40	11.63	12.46
IoDT	2017	2.52	8.81	5.46	5.70	3.22	3.17	4.79
	2019	3.02	10.73	6.73	6.50	3.89	4.16	5.74
	2022	3.79	14.77	9.02	8.46	5.40	5.72	6.96
DPS	2017	1.85	16.78	11.68	10.37	9.52	8.58	9.07
	2019	2.96	19.00	13.55	12.64	11.27	10.55	10.57
	2022	5.26	22.79	16.84	16.11	14.35	13.94	13.00

Source: *own elaboration based on DESI data*

With respect to Human Capital dimension country comparison portrayed an increasing trend of all indicators for all EU27 countries that was also true for Visegrad countries. Finland showed the best Human Capital index among EU27. Meanwhile, among Visegrad countries, Czech Republic consistently ranked highest, indicating strong educational and skill development outcome. Comparison of the four Visegrad countries with EU27 disclosed these four countries had lower Human Capital index relative to EU27, however in the case of the Czech Republic in 2022 the gap was not substantial.

With respect to Connectivity, the statistics showed a notable increasing trend with score more than doubling over this period and highest results recorded by Denmark in 2022. This indicates significant improvements in digital infrastructure and access across 2017 to 2022. Across Visegrad countries, Hungary outperformed the other three countries (in the pre-pandemic period performing even better than the EU27 on average), what reflects better infrastructure investment on digital connectivity. The difference between Visegrad and EU27 performance revealed that in the prepandemic period (2017-2019) Visegrad countries had lower Connectivity index but the difference was not significant. However, during the pandemic period, the competitiveness of the V4 countries in this area was reduced.

Similar to other sub-indices discussed earlier, there was clear evidence of increasing trend of Integration of Digital Technology in EU27 and Visegrad countries. While Finland led in Human Capital and Denmark led in Connectivity, these two countries displayed the highest Integration of Digital Technology among EU27 in 2022. Between the four Visegrad countries, the greatest Integration of Digital Technology score belonged to Czech Republic followed by Slovakia, Poland and Hungary. V4 countries are still far lagging from the average EU27 as well as Finland's performance. These findings document the importance of targeted policy intervention to bridge gaps of Visegrad countries and the EU benchmarks in the area of digital technology integration.

The descriptive statistics of Digital Public Services also indicate steady development in Digital Public Services from 2017 to 2022 reflecting enhanced efficiency and accessibility of public service through digital platforms in EU27 as well as in Visegrad countries. The highest score in the analyzed period among EU27 was recorded by Estonia, followed by Finland. The distribution ranged between countries indicating substantial variability. Across Visegrad countries, once again Czech Republic also led in Digital Public Services suggesting efficient public service digitalization. The results across the Visegrad countries suggest disparities in digital public service delivery capabilities and infrastructure, deviating negatively from those recorded on average in the EU27. The V4 countries are significantly behind, highlighting a need for strategic investments and reforms in public sector digitalization.

3.2. Digitalization trends and the digital divide in V4 countries in the years 2017-2019

To gain a deeper understanding of the changes in digitalization levels and the digital divide within the Visegrad countries over specific time periods, we employed the Ward method to analyze the average annual absolute increments of the DESI index and its sub-indices. This analysis aimed to identify countries with similar digitalization development patterns and to determine the V4 countries' trajectory within this context. To further enrich our analysis, we compared the V4 countries' progress against both the average cluster performance and the EU-27 average. Based on the output DESI and sub-indices data we also assessed the evolution of the digital divide in the analysed sub-periods by calculating the difference between the EU-27 or the digital leader's average performance and the individual V4 countries' results. Through these analyses, we were able to evaluate the V4 countries' efforts to bridge the digital divide at various levels.

We identified four distinct groups of EU countries in the pre-pandemic (2017-2019) period. *Figure 1* displays the dendrogram for the pre-pandemic period, while *Table 2* provides the average performance of the identified clusters.

In the years 2017-2019, i.e. before the Covid-19 pandemic, the V4 countries were included in three different clusters showing similarity of changes: the Czech Republic and Poland were included in cluster 1, Slovakia – in cluster 2, and Hungary – in cluster 3.

Compared to other clusters, cluster 1, on average, showed the highest average annual absolute increment in overall digitalization (measured by DESI) and its sub-indices for Integration of Digital Technology and Digital Public Services. It also grouped countries that achieved, on average the second-highest annual progress in Connectivity and the second-lowest in Human Capital dimension. These average characteristics exceeded the EU-27 average.

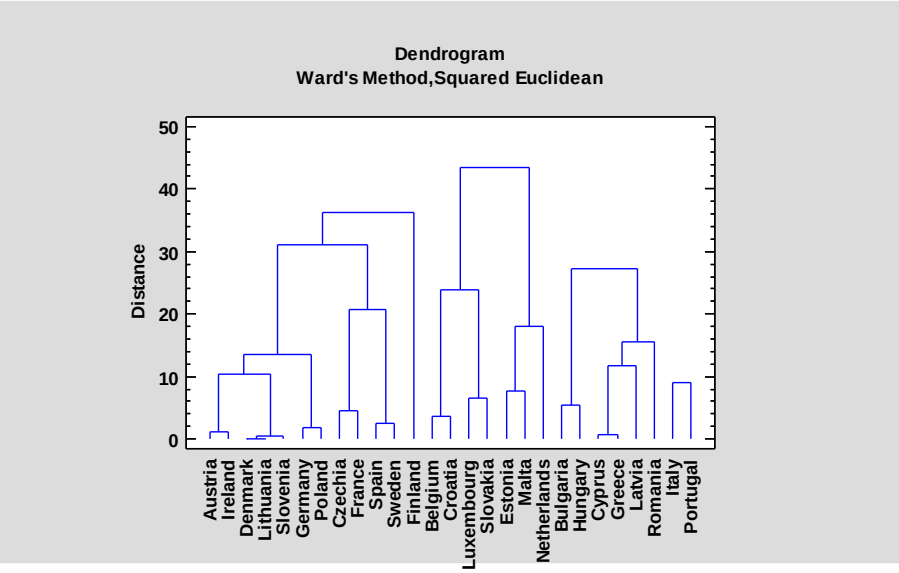

Figure 1. Ward's dendrogram for the EU-27 Member States for the pre-pandemic period.
Source: *Our own study based on DESI data*

Table 2. The average performance of clusters isolated for the pre-pandemic period

Cluster	Members	HC	Conn	IoDT	DPS	DESI
1	Austria, **Czechia**, Denmark, Finland, France, Germany, Ireland, Lithuania, **Poland**, Slovenia, Spain, Sweden	0.186	0.849	0.677	1.058	2.7700
2	Belgium, Croatia, Estonia, Luxembourg, Malta, Netherlands, **Slovakia**	0.430	0.360	0.619	0.895	2.3036
3	Bulgaria, Cyprus, Greece, **Hungary**, Latvia, Romania	0.033	0.608	0.378	0.761	1.7794
4	Italy, Portugal	0.193	1.209	0.558	0.795	2.7547

Source: *Our own study*

Before the pandemic, the Czech Republic and Poland resembled many EU-14 countries like Austria, France, and Germany, as well as top-ten DESI 2017 countries like Finland, Denmark, Sweden, Ireland, and Spain. They also shared similarities with post-socialist countries like Slovenia and Lithuania. The Czech Republic generally performed above or near the cluster's average in all digitalization dimensions, except for Integration of Digital Technology, where it underperformed the EU-27 average (*table 3*). In contrast, Poland lagged behind both the cluster and EU-27 averages in terms of overall digitalization and its sub-indices for Connectivity and Integration of Digital Technology. The latter dimension, in particular, showed a significant deviation from both average values.

As a result of these changes between 2017 and 2019 the Czech Republic exceeded the EU27 average score in the area of Human Capital and narrowed its digital gap with the EU-27 average in Connectivity and Digital Public Services. Poland reduced the divide in relation to the EU-27 average in Human Capital and Digital Public Services, while the Connectivity gap remained relatively stable. Moreover, in the analysed period, both countries outperformed Finland (also in the same cluster) in terms of average annual progress in Human Capital dimension, leading to a narrowing of the digital divide in this area also in relation to the leader

of the DESI ranking. The Czech Republic also made strides in reducing the gap with Finland in Digital Public Services.

Table 3. Selected characteristics on the performance of V4 countries in the period 2017-2019

Country	HC	Conn	IoDT	DPS	DESI	HC	Conn	IoDT	DPS	DESI
	The ratio of the average annual absolute increment of the index in a country to the average annual absolute increment of the index for the cluster (%)					The ratio of the average annual absolute increment of the index in a country to the average annual absolute increment of the index for the EU-27 (%)				
Czechia	155.0	100.4	59.1	107.4	96.6	176.8	117.1	62.9	121.2	108.6
Hungary	9.1	123.8	88.7	114.4	110.2	1.8	103.4	52.7	92.8	79.6
Poland	115.6	85.7	73.5	92.9	87.5	131.9	100.0	78.3	104.9	98.4
Slovakia	69.1	59.5	76.6	83.6	75.3	182.2	29.5	74.6	79.8	70.4
	Change in the divide between the EU-27 performance and country's performance in 2019 compared to 2017					Change in the divide in 2019 compared to 2017: (-) reduction; (+) increase				
Czechia	-0.2505	-0.2487	0.4717	-0.3976	-0.4252	(-)	(-)	(+)	(-)	(-)
Hungary	0.3200	-0.0499	0.6016	0.1342	1.0059	(+)	(-)	(+)	(+)	(+)
Poland	-0.1039	0.0002	0.2766	-0.0917	0.0812	(-)	(+)	(+)	(-)	(+)
Slovakia	-0.2680	1.0268	0.3233	0.3779	1.4600	(-)	(+)	(+)	(+)	(+)
	Change in the divide between Finland's performance and country's performance in 2019 compared to 2017					Change in the divide in 2019 compared to 2017: (-) reduction; (+) increase				
Czechia	-0.2969	0.0316	1.3338	-0.1306	0.9380	(-)	(+)	(+)	(-)	(+)
Hungary	0.2737	0.2304	1.4638	0.4012	2.3691	(+)	(+)	(+)	(+)	(+)
Poland	-0.1503	0.2805	1.1387	0.1754	1.4444	(-)	(+)	(+)	(+)	(+)
Slovakia	-0.3144	1.3071	1.1854	0.6450	2.8232	(-)	(+)	(+)	(+)	(+)

Source: *own elaboration based on DESI data*

The third country of the Visegrad Group - Slovakia - was included in cluster 2, alongside highly digitally developed countries such as the Netherlands, Luxembourg, Malta and Estonia, as well as those with a slightly lower level of digitalization such as Belgium or Croatia. This cluster distinguished itself by exhibiting the highest average annual absolute increment in the Human Capital dimension among all clusters. It also ranked second in the Integration of Digital Technology and Digital Public Services dimensions. However, it recorded the second-lowest overall DESI score and the lowest score in Connectivity. Notably, only the average annual absolute increment in the Human Capital dimension within this cluster exceeded the EU-27 average. While Slovakia's overall digital performance within this cluster was below average, it demonstrated significant progress in Human Capital development. Its average annual absolute increment in Human Capital significantly surpassed the EU-27 average and even outpaced Finland, the DESI leader. This rapid improvement contributed to narrowing the digital skills gap within the country (*table 3*). However, Slovakia's performance in other areas, particularly in Connectivity, was significantly weaker compared to the EU-27 and Finland. This resulted in a widening of the digital divide compared to 2017 in areas beyond Human Capital, especially in terms of access. In summary, during the pre-pandemic period, Slovakia successfully narrowed its digital skills gap but faced challenges in improving connectivity and overall digitalization, leading to a widening of other digital divides.

The last country - Hungary - was categorized in Cluster 3, comprising countries with the lowest overall digitalization levels in 2017, with the exception of Latvia, which held the 10th position in the DESI ranking. The countries grouped in this cluster were characterized by the lowest (or almost the lowest) average annual absolute increment of indices in all the areas

studied, exhibiting a slower pace of digital progress compared to the EU-27 average results. Relative to the cluster average, Hungary exhibited stronger average annual increment in Connectivity, Digital Public Services, and overall DESI scores. Conversely, it demonstrated weaker increment in Integration of Digital Technology and the lowest performance in Human Capital among cluster members (*table 3*). When comparing the average annual absolute increment in Hungary to that of the EU-27, Hungary exhibited outperformance only in the Connectivity dimension. In other areas, the increment was lower, with particularly negative progress observed in the Integration of Digital Technology and Human Capital dimensions. This pace of change resulted in an increased lead for Hungary over the EU-27 average in Connectivity by 2019, while the gap widened in other areas. In relation to the results of the digital leader, Finland, the gap widened across all dimensions analyzed.

3.3. Digitalization trends and the digital divide in V4 countries in the years 2019-2022 and 2017-2022

Based on the results achieved during the pandemic period (2019-2022), the Visegrad countries were categorized into two distinct clusters. The Czech Republic and Poland were assigned to Cluster 1, whereas Slovakia and Hungary were grouped in Cluster 2. *Figure 2* presents the dendrogram illustrating this clustering and *Table 4* provides the average performance for each of the isolated clusters.

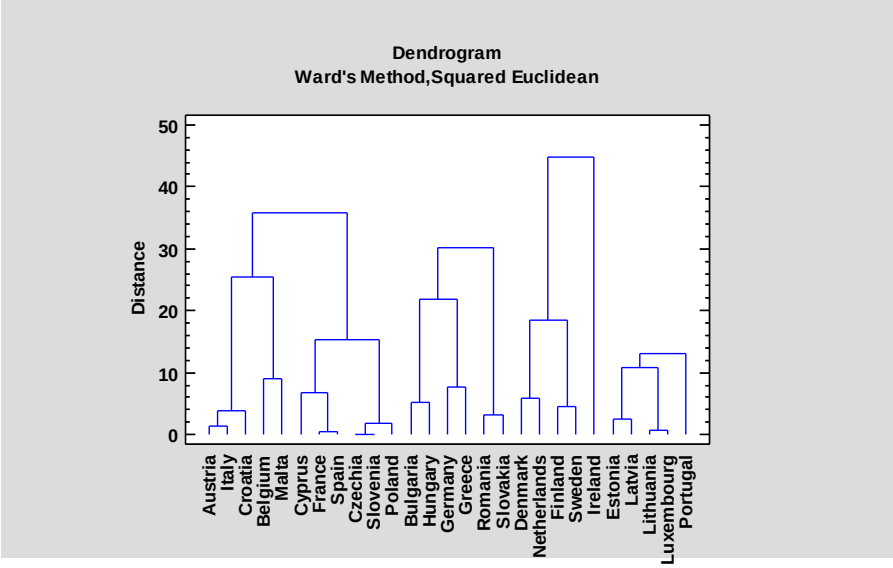

Figure 2. Ward's dendrogram for the EU-27 Member States for the pandemic period.
Source: *Our own study based on DESI data*

Table 4. The average performance of clusters isolated for the pandemic period

Cluster	Members	HC	Conn	IoDT	DPS	DESI
1	Austria, Belgium, Croatia, Cyprus, **Czechia**, France, Italy, Malta, **Poland**, Slovenia, Spain	0.190	2.149	0.835	1.160	4.3344
2	Bulgaria, Germany, Greece, **Hungary**, Romania, **Slovakia**	0.220	2.184	0.453	0.897	3.7535
3	Denmark, Finland, Ireland, Netherlands, Sweden	0.429	2.408	1.152	1.270	5.2591
4	Estonia, Latvia, Lithuania, Luxembourg, Portugal	0.403	1.106	0.682	1.192	3.3837

Source: *Our own study*

Our analysis revealed that the Czech Republic and Poland exhibited comparable patterns of digitalization change also during the pandemic period. Compared to the other clusters, Cluster 1 exhibited the second-highest average annual absolute increment in overall digitalization (measured by DESI) and Integration of Digital Technology, but also the second-lowest results in Connectivity and Digital Public Services. Furthermore, this cluster demonstrated, on average, the lowest average annual absolute increment in Human Capital score. Compared to the EU-27 average, Cluster 1 exhibited higher growth only in Integration of Digital Technology and Digital Public Services. Regarding the pattern of digitalization changes, the Czech Republic and Poland exhibited again similarities with several EU countries, including 'Old Union' members like Austria, France, Italy, and Spain, as well as newer members such as Croatia, Slovenia, Cyprus, and Malta.

The Human Capital dimension was the sole area where both the Czech Republic and Poland exhibited an above-average annual absolute increment relative to the cluster average. Conversely, both countries demonstrated below-average performance in the Integration of Digital Technology dimension, and Poland additionally in the Connectivity dimension. The other results were closely aligned with the average characteristics of the cluster (*Table 5*). The Czech Republic's average annual absolute increment exceeded the EU-27 average only in Digital Public Services, reaching 80-90% of the EU-27 average in other areas. Consequently, only Digital Public Services narrowed the gap with the EU-27 average between 2019 and 2022 and the Czech Republic lost its lead over the EU average in the area of Human Capital. Poland demonstrated a higher average annual absolute increment than the EU-27 in Human Capital and Digital Public Services, resulting in a slight reduction of the digital divide in these areas. With regard to the digital leader Finland, the digital gap in both countries widened across all dimensions. This disparity can be attributed to Finland's membership in the cluster exhibiting the highest average annual absolute increment across all analyzed indices, surpassing the progress achieved by the Czech Republic and Poland.

During the pandemic, Hungary and Slovakia were grouped in Cluster 2, exhibiting similar digitalization trends to countries like Bulgaria, Romania, Greece, and Germany. Characteristically, this cluster exhibited the second-highest average annual absolute increment in Connectivity, while displaying the second-lowest performance in overall digitalization level and Human Capital. Furthermore, it recorded the lowest average annual growth in Integration of Digital Technology and Digital Public Services. All these characteristics fell below the average observed for the EU-27. Slovakia's performance exceeded the cluster average only in Human Capital dimension, reaching 84.2-90.5% in other areas. Human Capital was also the sole dimension where Slovakia outperformed the EU-27, narrowing the digital divide. However, the gap with Finland, as in the case of the Czech Republic and Poland, widened across all dimensions due to Finland's significantly faster pace of change. Hungary, on the other hand,

outperformed Cluster 2 countries in overall digitalization, Integration of Digital Technology, and Digital Public Services. However, its performance lagged behind the EU-27 average in all dimensions, widening the digital divide in the analyzed period. The initial advantage of Hungary's access performance over the EU-27 average in pre-pandemic period was subsequently lost. Notably, Hungary's performance in Connectivity, coupled with Finland's slower growth rate compared to the EU-27 average, contributed to a narrowing of the first level digital divide relative to the DESI leader.

Table 5. Selected characteristics on the performance of V4 countries in the period 2019-2022

	HC	Conn	IoDT	DPS	DESI	HC	Conn	IoDT	DPS	DESI
Country	The ratio of the average annual absolute increment of the index in a country to the average annual absolute increment of the index for the cluster (%)					The ratio of the average annual absolute increment of the index in a country to the average annual absolute increment of the index for the EU-27 (%)				
Czechia	114.7	91.0	78.2	99.9	92.0	90.0	80.0	85.8	105.8	87.7
Hungary	75.8	99.0	110.6	114.6	102.8	68.8	88.5	65.8	93.9	84.9
Poland	136.8	78.2	62.2	97.5	82.9	107.4	68.7	68.2	103.3	79.0
Slovakia	156.7	84.2	89.4	90.3	90.5	142.4	75.2	53.2	73.9	74.8
	Change in the divide between the EU-27 performance and country's performance in 2022 compared to 2019					Change in the divide in 2022 compared to 2019: (-) reduction; (+) increase				
Czechia	0.0727	1.4655	0.3248	-0.1892	1.6739	(+)	(+)	(+)	(-)	(+)
Hungary	0.2263	0.8461	0.7814	0.2015	2.0554	(+)	(+)	(+)	(+)	(+)
Poland	-0.0536	2.2937	0.7271	-0.1068	2.8604	(-)	(+)	(+)	(-)	(+)
Slovakia	-0.3078	1.8193	1.0692	0.8567	3.4373	(-)	(+)	(+)	(+)	(+)
	Change in the divide between Finland's performance and country's performance in 2022 compared to 2019					Change in the divide in 2022 compared to 2019: (-) reduction; (+) increase				
Czechia	0.7492	0.4409	2.0806	0.2277	3.4984	(+)	(+)	(+)	(+)	(+)
Hungary	0.9029	-0.1785	2.5372	0.6184	3.8799	(+)	(-)	(+)	(+)	(+)
Poland	0.6230	1.2691	2.4829	0.3100	4.6850	(+)	(+)	(+)	(+)	(+)
Slovakia	0.3687	0.7947	2.8250	1.2735	5.2619	(+)	(+)	(+)	(+)	(+)

Source: *own elaboration based on DESI data*

Analysis of the entire period covering the years 2017-2022 revealed that the Czech Republic, Poland, and Slovakia demonstrated a narrowing of the digital divide in citizens' digital skills (Human Capital), with Slovakia exhibiting the most significant progress relative to the EU-27 average. The Czech Republic and Poland also achieved a reduction in the digital divide in terms of the level of digitalization of public services, with the Czech Republic demonstrating more substantial progress. In contrast, Hungary experienced a widening of the digital divide in all dimensions, including Connectivity, despite previously outperforming the EU-27 average in this area. While three countries managed to narrow the skills gap and two the digital public services gap, all four countries experienced a deterioration in Connectivity and Integration of Digital Technology area (*Table 6*).

Table 6. Selected characteristics on the performance of V4 countries in the period 2017-2022

Country	HC	Conn	IoDT	DPS	DESI	HC	Conn	IoDT	DPS	DESI
	Change in the divide between the EU-27 performance and country's performance in 2022 compared to 2017					Change in the divide in 2022 compared to 2017: (-) reduction; (+) increase				
Czechia	-0.1778	1.2168	0.7965	-0.5868	1.2487	(-)	(+)	(+)	(-)	(+)
Hungary	0.5464	0.7962	1.3831	0.3357	3.0613	(+)	(+)	(+)	(+)	(+)
Poland	-0.1575	2.2939	1.0037	-0.1985	2.9416	(-)	(+)	(+)	(-)	(+)
Slovakia	-0.5758	2.8461	1.3925	1.2346	4.8974	(-)	(+)	(+)	(+)	(+)
	Change in the divide between Finland's performance and country's performance in 2022 compared to 2017					Change in the divide in 2022 compared to 2017: (-) reduction; (+) increase				
Czechia	0.4524	0.4725	3.4144	0.0971	4.4364	(+)	(+)	(+)	(+)	(+)
Hungary	1.1765	0.0519	4.0010	1.0196	6.2490	(+)	(+)	(+)	(+)	(+)
Poland	0.4727	1.5496	3.6216	0.4854	6.1293	(+)	(+)	(+)	(+)	(+)
Slovakia	0.0543	2.1018	4.0104	1.9185	8.0851	(+)	(+)	(+)	(+)	(+)

Source: *own elaboration based on DESI data*

With regard to the EU digital leader Finland, its performance significantly improved during the pandemic, widening the gap with the V4 countries in most dimensions. Hungary was an exception, narrowing the Connectivity gap with Finland. However, over the entire 2017-2022 period, even Hungary experienced a widening of the digital divide in Connectivity, highlighting Finland's strong overall performance.

4. Discussion

Several recent studies have examined the issue of the digital transformation and the development asymmetries occurring in this respect across the EU, including the V4 countries. Our research builds on the previous research but pays special attention to the performance achieved by four Visegrad countries. Our research revealed that the V4 countries in the period analyzed achieved varying levels of digitalization as measured by the DESI, which is a consequence of the different performance in the four dimensions analyzed. Visegrad countries generally displayed greater scores of the four main sub-indices, year by year that also evidenced in EU27 and Finland. The analysis revealed significant gaps between the Visegrad countries, the EU27 average, and Finland in key areas of digitalization. While the gaps with the EU27 were generally moderate, the disparities with Finland were significant across all dimensions, as Finland sets a high benchmark with its advanced digital infrastructure, skilled workforce, highly digitalized business sector and comprehensive digital public services. However, while individual V4 countries differ in the rank achieved due to the index value and structure, several overarching digital development trends are evident. Hungary, Poland, and Slovakia consistently demonstrated lower levels of digitalization throughout the analysis period. In contrast, the Czech Republic generally exhibited a slightly more favorable digitalization performance. These findings consistently support the observation of a relative digital advantage for the Czech Republic within the V4 context and are largely consistent with those of other authors (Kiseľaková et al., 2021, Pekarcikova et al., 2021, Esses et al., 2021, Čerňanová & Stovíček, 2024).

Building upon existing research on digitalization within the EU, which has examined recent advancements, particularly during the COVID-19 pandemic and utilized various clustering methods to identify groups of countries with similar levels of digitalization and development trajectories, this study focused on the specific changes experienced by the V4

countries during the pre-pandemic and pandemic periods. Our findings align with those of other researchers, demonstrating that the COVID-19 pandemic served as a catalyst for the accelerated development of ICT infrastructure, the widespread diffusion of digital technologies, and the enhancement of digital skills. The pandemic significantly impacted all citizens and organizations, regardless of their size or activities (Burlea-Schiopoiu et al., 2023). Furthermore, public health measures and social distancing policies necessitated a fundamental shift towards a new digital society and economy (Ganichev & Koshovets, 2021, Döhring et al., 2021).

Cluster analysis revealed four distinct groups of countries exhibiting similar patterns in the pace and structure of digitalization across both sub-periods. Within the V4 group, notable differences emerged. Throughout both periods, the Czech Republic and Poland demonstrated comparable trajectories in terms of the pace and structure of change across the analyzed digitalization indices, consistently achieving higher average annual absolute increments compared to Slovakia and Hungary. The latter two countries followed slightly different digital development paths, showing similarity in the pace and structure of digital change only during the pandemic period.

There were different changes observed in the digital divide across V4 countries and sub-periods. During the pre-pandemic period, the Czech Republic demonstrated the most significant progress, narrowing the digital divide compared to the EU27 average across all dimensions except Integration of Digital Technology. Three out of four V4 countries (Czech Republic, Poland, and Slovakia) narrowed the digital skills gap, while two (Czech Republic and Hungary) improved their performance in ICT access. Similarly, two countries (Czech Republic and Poland) narrowed the gap in digital public services compared to the EU27 average. We can conclude that only some of the V4 countries managed to narrow the digital divide at the analysed two levels and these results are in line with the findings of other scholars.

Farkačová et al. (2023) attributed the higher levels of digital literacy in the Czech Republic and Slovakia compared to Hungary between 2015 and 2020 to their stronger emphasis on educational reforms and investments in technology infrastructure. These countries prioritized developing digital skills through comprehensive government policies and various initiatives, such as widespread access to educational resources, digital training programs, and technology integration in schools, resulting in a more technologically advanced workforce and higher information literacy rates compared to Hungary. Also Cseh-Zelina (2023) observed that while Hungary implemented several programs to enhance citizens' digital skills during this period, these efforts did not significantly impact the relevant indicators. However, the study highlights the effectiveness of Hungary's investments in digital infrastructure development. These investments substantially improved the country's performance in this area, contributing to a narrowing of the first-level digital divide, a finding corroborated by our own research. In turn, Piątkowski & Misztal (2022) observed a systematic improvement in Poland's public sector digitalization, emphasizing its positive impact on the accessibility and quality of public services.

During the pandemic period, our analysis revealed significant disparities in the pace of digitalization across EU member states, a finding consistent with recent literature (Georgescu et al., 2022, Pisar et al., 2024). While the pandemic accelerated the pace of digitalization across all 27 EU countries, both cluster analysis and comparisons to the EU27 average and Finland's performance indicated that the V4 countries experienced insufficient progress to significantly narrow the digital divide in many areas. Specifically, the Czech Republic and Poland continued to narrow the digital divide in Digital Public Services and Poland and Slovakia narrowed the gap in the Human Capital dimension. However, the Czech Republic experienced a reversal in the positive trend in Human Capital, and both the Czech Republic and Hungary – in Connectivity. In other cases, negative trends persisted, leading to a further widening of the

digital divide. Therefore, while the pandemic narrowed the skills and digital public services gaps in two countries, it simultaneously exacerbated the Connectivity and Integration of Digital Technology gaps across all four V4.

Considering the entire period covering 2017-2022 the narrowing of the digital skills divide in the Czech Republic, Poland and Slovakia should be regarded as a particularly positive trend, since it fosters a more inclusive and competitive society, empowers individuals, and strengthens the foundation for future growth in the digital age. As Maziarz (2023) emphasizes, adequate digital skills are a crucial prerequisite for the successful development of an information society, which by its nature should be characterized by innovation, dynamic technological progress, and competitiveness. Furthermore, research by Laitsou et al. (2020) highlights the critical role of digital skill enhancement, alongside broadband penetration, in driving economic growth and mitigating inequality within the EU. The study underscores the importance of targeted investments in these areas to effectively bridge the digital divide. The reduction of the usage divide in public services in the Czech Republic and Poland is a positive development. It enhances the quality of life for citizens, facilitates business operations, and encourages greater utilization of ICT (Fischer et al., 2021). A concerning observation was made regarding Hungary's performance over the entire period: the digital divide failed to narrow in any of the dimensions studied. However, despite this overall challenge, Hungary exhibited exceptional advancement in Connectivity among the V4 countries. However, throughout the whole analyzed period, the V4 countries failed to reduce the gap between themselves and the digital leader, Finland.

Our research evidenced, similarly as those of the other authors, that Internet penetration and physical access to the Internet was growing in recent years across the whole Europe, but particularly in technologically advanced countries (Ragnedda & Kreitem, 2018). For this reason the differences in terms of access still persist. The V4 countries have struggled to keep pace with the improvement observed in the EU-27 average in this area. The efforts in boosting the Internet infrastructures and all the associated policies adopted were not sufficient to close the first level digital divide in these countries.

Digitalization efforts in the V4 countries also failed when it comes to the second level divide related to digitalization of the business sector, especially SMEs, what was also evidenced by studies of Hunady et al. (2022) and Kovács et al. (2023). V4 countries performance in the area of digitalization of business remained well below the EU-27 average with important progress still needed in terms of the uptake of advanced technologies. However, this underperformance can be partly attributed to the specific economic structures of these countries. Historically, the V4 economies relied on low-tech and low-skilled industries and services, low labor costs and EU funding, to drive economic growth (Kordalska & Olczyk, 2021). Furthermore, they exhibit a high dependence on foreign capital (FDI). Beyond the foreign-owned automotive and electronics sectors, V4 countries are less prepared for the digital transition compared to many Western European counterparts (Szabo, 2020). In particular, SMEs, which constitute a significant portion of their economies, exhibit low adoption rates of digital technologies (Chetverikova, 2023). Domestic firms lag behind foreign companies in digitalization due to factors such as low levels of innovation and limited access to financing (Rosak-Szyrocka et al., 2021, Krajčík, 2021, Olšanová et al., 2021). This persistent reliance on foreign-owned firms will further strengthen the dependence of the V4 digitalization model, particularly in relation to Industry 4.0 technologies, hindering the rapid digitalization of the business sector within these countries (Éltető et al., 2022). Our findings underscore the complex nature of the technology adoption challenge, highlighting that it extends beyond mere access or skills issues (Kurakova et al., 2021). Ensuring the positive spillover effects and knowledge transfer from advanced foreign firms to local companies is crucial for driving broader business

digitalization. It's important to note that this challenge is not unique to the V4 countries. Some studies evidenced that countries classified as digital access leaders, having advanced digital infrastructure and high levels of digital access, record also an imbalance or underperformance in the uptake of digital technologies in the business sector (Pinto *et al*., 2023; OECD, 2021). These studies point to a potential mismatch between available digital infrastructure and the effective implementation of digital technologies within enterprises, often due to a lack of necessary infrastructure or resources at the company level.

Despite significant efforts made in recent years to bridge the digital divide at various levels in Visegrad countries, our research indicates that they are not very effective and do not bring such tangible results as in many other EU countries. In fact, the digital divide has widened in most of the dimensions analyzed. These gaps highlight the need for targeted investments in digital infrastructure, education, and public services. Enhancing digital skills and connectivity can enable the V4 countries to better leverage digital technologies, improve public service delivery, and foster economic growth. Addressing these challenges will require comprehensive digital strategies, public-private partnerships, and a focus on inclusive digital transformation.

Conclusions

As stated in the introduction, the primary purpose of this study was to analyze and assess the digital divide between the Visegrad countries and the remaining 27 EU member states during the period 2017-2022. We have shown how strongly digital divide in terms of digital access, digital skills and use is evident between these countries and other EU Members. Furthermore, we have highlighted the strengths and weaknesses of digital development within each of the V4 countries. Finally, we have identified key similarities and contrasts in the digital divide across these countries during two distinct sub-periods: the pre-pandemic and pandemic years.

Our findings reveal significant disparities in the level of digital development among the V4 countries, with varying performance across the four key dimensions of digitalization compared to both the EU-27 average and the leading digital performer, Finland. This research underscores the heterogeneity of the V4 group, demonstrating that it cannot be considered a homogenous bloc with a uniform level of digital development. Significant digital inequalities persist within the region, encompassing access, digital skills, and ICT usage, reflecting varying levels of digital transformation progress across the countries. The Czech Republic consistently outperformed the other V4 countries, exhibiting higher levels of ICT access, digital skills, and digital use in both the business and public sectors. This consistent superior performance positions the Czech Republic as a potential benchmark for digitalization efforts within the V4 region. Our findings emphasize the critical need for targeted policy interventions to bridge the digital divide within the V4 countries and align them more closely with EU benchmarks. Policymakers can leverage these insights to identify areas requiring improvement based on benchmarking analyses, and subsequently plan for targeted investments in digital infrastructure, policy development, and a robust framework for digital transformation.

Our analysis reveals a mixed picture regarding the narrowing of the digital divide within the V4 countries compared to the EU average. While progress has been observed in some areas, such as digital skills and public service digitalization, significant challenges remain. Furthermore, the positive trends in these areas have not been consistently mirrored in the business sector, suggesting that a broader set of factors influence ICT adoption within businesses. These findings necessitate a critical re-evaluation of national strategies for business digitalization, as current approaches have not yielded the anticipated results. However, it is

anticipated that the growing pool of digitally educated individuals will drive increased ICT usage within these countries in the near future.

This study, while comprehensive in its analysis of the digital divide among V4 countries compared to the EU, has certain limitations. Firstly, the analysis focuses on national-level data, precluding an in-depth examination of the digital divide within each V4 country. Secondly, the study does not delve into the specific root causes of the observed disparities in digital divide levels across the V4 countries. The identified trends, particularly the widening of the digital divide in certain areas, necessitate further research to pinpoint the underlying factors contributing to this slow progress. Conversely, the superior performance of the Czech Republic warrants further investigation to identify the factors contributing to its success and explore their potential applicability to other V4 countries. Finally, the study, based on DESI indicators, primarily focuses on the first and second levels of the digital divide, neglecting the third level, which pertains to the offline impacts of ICT. However, the findings of this study provide a solid foundation for future empirical research aimed at understanding the concrete offline outcomes resulting from differentiated access, digital literacy, and ICT usage.

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