Digital Inequality in EU Countries: Effects on E-Government Services

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Abstract

In today's world, digital technologies are becoming an integral part of everyday life, particularly evident in public administration, where e-governance ensures efficiency, transparency, and accessibility of services for citizens. However, digital inequality continues to be a significant issue in European Union countries, manifesting in various forms such as disparities in broadband coverage, access to networks, and skills in using digital tools. This research analyzes the impact of digital inequality on the use of e-government services in EU countries, identifying key factors that influence user activity. The results show that, despite positive trends in reducing digital inequality, the level of digital skills leaves much to be desired. The use of cluster analysis methods allowed for the identification of two main groups of countries with varying levels of digital technology development and skills. For countries facing significant infrastructure challenges, it is crucial to attract investment for the development of digital infrastructure, while countries with positive dynamics should focus on improving the digital skills of their populations. The research highlights the need for policy adaptation to ensure equal access to e-government services and promote social cohesion in the EU.

Keywords

digital inequality, e-governance, EU countries, access to public services, digital skills, cluster analysis, broadband internet

1. Introduction

In today's world, digital technologies have become an integral part of everyday life, contributing to the development of economies and changes in social structures. Their use in public administration is particularly important, where e-governance ensures the efficiency, transparency, and accessibility of public services for citizens. However, despite the increasing adoption of digital solutions, digital inequality remains a significant issue in many countries, particularly in European Union (EU) countries.

Digital inequality manifests in various forms, such as disparities in broadband coverage, access to networks, and the skills required to use digital tools. These inequalities can have serious consequences for the effectiveness of e-governance, as they limit the opportunities for certain population groups, including low-income individuals, the elderly, and persons with disabilities. Thus, studying the impact of digital inequality on e-governance in EU countries is extremely relevant.

This research focuses on analyzing digital inequality and its impact on the use of e-government services in EU countries, as well as identifying factors that influence user engagement in e-governance through websites. Therefore, the aim of this article is to highlight the importance of addressing digital inequality to ensure fair and equal access to public services in the context of the modern digital economy.

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2. Literature review

A review of scientific research on digital inequality allows for an understanding of its impact on economic development and social cohesion in European Union countries. This body of literature highlights the multifaceted nature of digital inequality, emphasizing the need for comprehensive strategies to bridge the digital divide and promote equitable access to technology across diverse populations.

For instance, Robinson, L., Schulz, J., Blank, G., Ragnedda, M., Ono, H., Hogan, B., Mesch, G.S., et al. (2020) [1] note that 2020 marks the 25th anniversary of the concept of "digital inequality." Despite the passage of a quarter of a century, inherited digital inequalities remain relevant, and new forms of inequality continue to grow. The major gaps identified in 1995 still affect society. Among the main issues are inequalities in access to digital technologies that divide "digital haves" and "have-nots" both within and between countries. Moreover, even in populations with widespread internet access, there are inequalities in skills and technology usage related to economic class, gender, race, age, health, education, and geographic location. The authors introduce the concept of the "digital inequality stack," which encompasses access to communication networks, devices, and software, as well as collective access to infrastructure. This concept emphasizes that inequalities at the foundational level often lead to inequalities at higher levels. As a result, all levels of the digital inequality stack can interact with one another, exacerbating overall disparities.

Defining digital inequality as a problem with a complex impact on society creates a foundation for addressing the current challenges faced by various population groups in the context of the pandemic. Beaunoyer E., Dupéré S., and Guitton M.J. (2020) in their article [2] explore how the COVID-19 pandemic transformed digital spaces from an opportunity into a necessity, becoming a primary means of access to information, services, and social interactions. Despite this, not everyone has equal access to the internet, connected devices, and necessary skills, leading to exacerbated digital inequality. Crisis conditions not only deepen this inequality but also increase the vulnerability of the population to the virus. The article analyzes the mutual influence of COVID-19 and digital inequality, identifying digital inequality as a significant health factor. To mitigate the impacts of the crisis, the authors propose multi-level strategies focused on practical actions at the governmental, corporate, and community levels.

These topics concerning the socio-economic consequences of the pandemic prompt a deeper analysis of digital communication under restrictions. Nguyen M. Hao, Hargittai E., and Marler W. (2021) [3] analyze how the COVID-19 pandemic affected digital communication amid physical distancing in their study. They use survey data from a national sample of 2,925 participants in the U.S., collected at the onset of the pandemic, to examine the relationship between socio-demographic characteristics, living conditions, and internet usage experience with changes in digital communication. The results indicated that individuals with privileged socio-economic status, better internet skills, and greater online communication experience were more likely to increase their use of digital communications and reduce it less during the pandemic. These findings demonstrate how digital inequalities can put already vulnerable groups in even greater danger due to reduced social contact during a crisis. The authors also discuss the theoretical implications of their findings for digital inequality research, practical recommendations for ensuring inclusivity during crises, and directions for future studies.

In light of these challenges, it is also important to explore the context of specific countries and their readiness for digital transformation. In the scholarly work [4] by Melnyk, M., Shchehliuk, S., Leshchukh, I., and Litorovych, O. (2021), the authors investigated digital inequality between Ukraine and Poland, highlighting differences in internet access levels and the development of digital skills among the population. The analysis showed that Ukraine significantly lags behind Poland in these indicators, which affects the overall level of the digital economy. National and regional disparities in access to broadband internet and digital technologies confirm the existence of digital inequality, which hinders economic growth and requires governmental support to accelerate digitalization, particularly through EU programs such as EU4Digital.

These results pertain not only to Europe but also to the global context, particularly in developing countries. Richard Heeks (2022) [5] points out that digital systems have a significant connection with inequality in Global South countries. Traditionally, this association has been viewed through the lens of the digital divide, which focuses on excluding certain groups from the benefits of digital systems. However, with the development of digital participation in regions of the Global South, such a perception is no longer sufficient. It is also essential to understand how inequalities arise for groups that are already included in digital systems. The article proposes a new concept of "negative digital integration," which refers to inclusion in a digital system that allows a more privileged group to derive disproportionate benefits from the work or resources of a less privileged group. This model will help researchers in digital development understand why, how, and for whom inequalities may arise in the process of increasing the use of digital systems in Global South countries. The article also offers a systematic framework that takes into account the processes, factors, and causes of negative digital integration, providing new detailed insights into this issue. Based on the findings of this research, the author outlines implications for researchers and practitioners in the field of digital development, drawing on this model and its connection to broader power components that shape the relationships between digital technologies and inequality.

These concepts help to understand how digital inequality manifests in practice and how it can be overcome. The importance of this topic is emphasized in the work of Trofymenko, M., Bulatova, O., et al. (2023) [6], which investigates the impact of digital inequality on socio-economic development. The authors focus on how limited access to technology exacerbates social and economic stratification. Their study explores ways to overcome this inequality, particularly through the integration of digital technologies into sustainable development policies, international cooperation, and the implementation of digital initiatives. Thus, based on this work, it becomes evident that comprehensive measures must be taken to achieve sustainable development goals. The authors also highlight the importance of a comprehensive assessment of the level of digital development in regions of the world for a deeper understanding of the unevenness and the potential application of digital technologies for economic growth, enhancing innovative activity, improving quality of life, and social cohesion. The implementation of such technologies fosters progress across various sectors, stimulating the development of the digital economy, increasing labor productivity, and access to public and private services.

In addition to this, Kuhn, C. et al. (2023) [7] proposed a new methodological toolkit, including a theoretical kaleidoscope, for analyzing the components of digital inequalities. They emphasized the importance of a critical approach to studying the "ideology of digitalism" and its implications for human flourishing. The article describes various theoretical approaches that can be utilized within this kaleidoscope and illustrates them with examples. This research also notes that the post-digital phase does not signify the end of the digital era but rather indicates a transformation of power structures. Thus, researchers emphasize the need for tools to uncover the invisible power structures and their impact on people's daily lives.

In the context of the aforementioned ideas, the scholarly work by Ahmed Imran (2023) [8] examines the multifaceted and far-reaching consequences of digital inequality, drawing on the latest trends and examples. The aim of the study is to draw the attention of policymakers, practitioners, and scholars to the issues related to digital inequality and to foster a deeper understanding of these issues among all stakeholders. The field of information and communication technologies has undergone significant changes due to its close interdependence with many other sectors, covering critical issues such as ethics, inequality, leadership, social capital, governance, and management. These aspects indicate that digital inequality is a complex problem that requires a multidisciplinary approach. There remains a significant gap in understanding the complexities associated with digital inequality, which varies across different contexts. The author of the article, drawing on over 15 years of experience in the ICT field, discusses the evolution of digital inequality in the context of social transformations and its increasing short-term and long-term consequences. Strategies and pathways for the future are presented, grouped into six directions: a call for the restoration of a philosophical approach and a campaign for digital equality, political interventions, inclusive technological solutions and services, comprehensive enhancement of human capabilities, the role of universities, and the necessity of a multidisciplinary approach to addressing the challenges of digital inequality.

In light of these challenges, the research by Perera, P. et al. (2023) [9] focuses on the impact of digital inequality on achieving sustainable development goals, emphasizing that digital inequality is one of the main causes of socio-economic disparities and a barrier to sustainable development. They conducted a systematic review of scientific publications using the PRISMA (2020) methodology and electronic databases, including 54 articles in the final database for qualitative analysis.

Heponiemi, T., Gluschkoff, K., Leemann, L., Manderbacka, K., Aalto, A.-M., & Hyppönen, H. (2023) in their article [10] examined the impact of rapidly developing digital medical and social services, which partially replace in-person services in developed countries, on digital inequality. In their population study among Finnish adults (N = 4,495), they explored the connections between offline resources and perceived benefits of online services, as well as the mediating effects of access, skills, and attitudes in these relationships. The results showed that individuals with lower personal, economic, and social offline resources perceived online services as less useful, which was explained by poor access to services, inadequate digital skills, and negative attitudes toward online services. To enhance equity, it is essential to improve access to the internet and digital skills, as well as to implement measures to address negative attitudes, especially among vulnerable groups. Additionally, online medical and social services should be designed with inclusivity principles in mind.

Thus, the findings of the research on digital inequality highlight the need to address this issue to achieve sustainable development goals and ensure the accessibility of online services. Studying digital inequality in the context of e-governance is extremely important, as ensuring the accessibility of electronic services must be fair for all, regardless of social status, region, or economic conditions. Digital inequality can lead to the exclusion of certain population groups from important government services.

Moreover, access to electronic services enhances communication between the government and citizens, improving the efficiency of management processes and reducing bureaucracy. Ensuring access to digital technologies also fosters more active citizen participation in democratic processes, supporting sustainable development. Addressing the issue of digital inequality can stimulate economic development by expanding opportunities for business and investment in digital technologies.

3. Methodology

To analyze digital inequality in European Union countries and its impact on the use of e-government services, a quantitative approach will be employed using statistical and econometric methods.

Several key indicators have been selected to comprehensively assess various aspects of digital inequality and its consequences (Table 1). It should be noted that, while the main criteria for clustering EU countries by the level of digital inequality, such as access to the Internet, digital skills, and investment in digital infrastructure, are important, additional parameters have been chosen to provide a more comprehensive and detailed view of digital inequality. These parameters include broadband Internet coverage by speed and technology, individuals' Internet usage, household access to the Internet, and individual digital skills, allowing for a broader assessment of the factors affecting the use of e-government services across different countries.

Table 1
Key Indicators for Analyzing Digital Inequality and Their Characteristics

Indicator	Characteristic
Broadband internet coverage by speed (More than 100 megabits per second (Mbps)), percentage of households	Internet connection speed is an essential factor since it determines the quality of access to e-government services. Higher speeds offer improved service quality, which is necessary for the effective delivery of many electronic services. Analyzing coverage by speed assists in identifying regions with inadequate access, potentially hindering their participation in e-governance.
Broadband internet coverage by technology (Next generation access), percentage of households	Different technologies offer varying levels of reliability and speed. Next-generation technologies typically provide higher reliability and speed, which can positively impact the utilization of e-government services. Examining technological coverage can aid in planning the development of digital infrastructure in EU countries.
Individuals – internet use (Last internet use: in the last 12 months), percentage of individuals	This indicator directly reflects the population's participation in the online environment and the use of e-government services, allowing for an assessment of how actively different demographic groups utilize online services. A decline in internet usage among certain groups may indicate the presence of digital inequality. This indicator highlights the level of citizen engagement in the digital space, which is crucial for the successful integration of e-governance.
Households – level of internet access, percentage of households	This indicator allows for an assessment of how widespread internet access is among households and which social groups may be excluded from the digital world. Internet accessibility in households is a key factor for accessing government online services, especially in the context of social inequality.
Individuals level of digital skills (Individuals who have basic information skills), percentage of individuals	Digital skills are fundamental for accessing and effectively using e-government services, as inadequate skills can hinder the efficient use of these services, even when internet access is available. Analyzing this indicator helps identify the need for additional education and training for the population, which can contribute to reducing digital inequality.

Thus, the selected indicators provide a comprehensive analysis of digital inequality in the context of e-government, allowing us to understand which factors influence access to public services in the current digital economy.

We will examine each of the chosen indicators in detail, assessing their contribution to the overall picture of digital inequality and the ways in which they may affect the level of use of public services through electronic platforms.

For the analysis, statistical data for the aforementioned indicators were used for each of the 27 EU countries [11]. The first step in our study of digital inequality in EU countries was to calculate descriptive statistics for the key indicators, which allows us to obtain an overall understanding of the data, identify major trends, and assess variation and extreme values in different countries.

This is an important stage, as it helps to identify problematic areas that require attention and can serve as a foundation for further analysis (Table 2).

Table 2
Descriptive Statistics of the Main Analysis Indicators

Descriptive statistics	Broadband internet coverage by speed	Broadband internet coverage by technology	Individuals – internet use	Households – level of internet access	Individuals level of digital skills
count	297	297	297	297	297
mean	66.71	80.79	84.90	85.46	29.45
std	25.14	16.24	9.79	9.35	30.10
min	0.40	20.90	54.82	53.71	2.09
25%	49.60	71.80	79.26	80.32	6.79
50%	68.90	84.40	86.61	87.71	10.78
75%	88.90	94.40	92.63	92.78	55.73
max	100.00	100.00	99.40	99.18	93.54

Broadband internet coverage by speed has an average of 66.71%, with a high standard deviation of 25.14, indicating significant discrepancies in access to high-speed internet across different countries. The minimum value (0.40%) suggests that some countries face serious challenges in accessing fast internet. Broadband internet coverage by technology is higher, with an average of 80.79%; however, the standard deviation (16.24) still indicates variation in the availability of different internet access technologies.

Internet usage among the population stands at 84.90%, demonstrating a high level of engagement with the online environment, but the standard deviation (9.79) suggests that not all demographic groups use the internet equally actively. The level of internet access in households is also high (85.46%), but, similar to other indicators, variations in the data indicate potential social or economic barriers for certain population groups. The level of digital skills is the lowest among all indicators, with an average of 29.45% and a large standard deviation (30.10). This indicates that there is a significant gap in digital skills proficiency in EU countries, which may affect the population's ability to effectively use e-government services.

Thus, even from descriptive statistics, it is evident that there are significant variations in internet access and levels of digital skills among different social groups. This underscores the need for further analysis, as descriptive statistics provide only a superficial view of inequality and do not reflect the depth and dynamics of this phenomenon.

To better understand whether digital inequality between EU countries is indeed decreasing, it is important to move to more robust analytical tools, such as calculating the Gini coefficient. This index not only quantitatively assesses the level of inequality but also analyzes how it changes over time.

The Gini coefficient provides a clear picture of resource distribution in society, which in this case can be adapted to assess access to various digital technology indicators. This will help us determine how equitably opportunities for accessing broadband internet, technologies, and digital skills are distributed among EU countries. In particular, we can compare Gini coefficients across different years to identify trends and changes in the level of inequality (Table 3). This analysis not only sheds light on disparities in digital access but also highlights the importance of inclusive policies that promote equitable access to technology for all citizens. Ultimately, understanding these dynamics is crucial for fostering a more connected and equitable digital landscape, which is essential for driving economic growth and enhancing social cohesion within the EU. Moreover, by identifying specific areas of inequality, policymakers can tailor their interventions to address the unique challenges faced by different demographics, ensuring that no group is left behind in the digital transformation.

Table 3
The Gini Coefficient for Indicators of Access to Digital Technologies in EU Countries

Year	Broadband internet coverage by speed	Broadband internet coverage by technology	Individuals – internet use	Households – level of internet access	Individuals level of digital skills
2013	0.3265	0.1795	0.0905	0.0895	0.2449
2014	0.2941	0.1538	0.0808	0.0773	0.1930
2015	0.2803	0.1402	0.0750	0.0657	0.1670
2016	0.2640	0.1131	0.0672	0.0593	0.1902
2017	0.2316	0.1010	0.0626	0.0543	0.1989
2018	0.1998	0.0842	0.0526	0.0403	0.2024
2019	0.1299	0.0693	0.0475	0.0377	0.2231
2020	0.1119	0.0603	0.0416	0.0298	0.0570
2021	0.0858	0.0509	0.0359	0.0248	0.0804
2022	0.0684	0.0500	0.0276	0.0211	0.0799
2023	0.0601	0.0404	0.0276	0.0180	0.0810

The data demonstrate a gradual reduction in digital inequality among EU countries across various indicators of access to digital technologies. From 2013 to 2023, the Gini coefficient for all these indicators has significantly decreased, indicating a leveling of digital technology usage between different countries.

Notably, the decline in the Gini coefficient for broadband coverage by speed, which dropped from 0.3265 in 2013 to 0.0601 in 2023, is particularly telling. This suggests that most EU countries are gradually achieving more uniform access to high-speed internet. A similar trend is observed for broadband coverage by technology, where the reduction in the coefficient from 0.1795 to 0.0404 indicates an improvement in the availability of advanced technologies across all countries.

Regarding internet usage levels among individuals and household access to networks, inequality has also significantly decreased. This points to a gradual leveling of opportunities for internet users regardless of their country. However, the indicator for digital skills presents a somewhat more complex picture: while the overall trend is also downward, there has been some stabilization of this coefficient in recent years compared to other indicators, which may suggest that certain countries still face challenges in enhancing their populations' digital skills.

Overall, the results indicate substantial progress in leveling digital development indicators across EU countries, although some aspects, particularly the level of digital skills, still require further attention.

In addition to the Gini coefficient, which is a classic measure of inequality, our research will also explore the concept of sigma convergence. This allows us to assess whether there is a reduction in dispersion among countries regarding digital indicators, such as internet access, digital skills levels, and other metrics over a specific period. Sigma convergence focuses on whether countries are becoming more homogeneous in terms of digital development indicators. This is an important aspect of the analysis because even if average levels of access to digital technologies are increasing, the distribution may still remain uneven among countries. Furthermore, investigating sigma convergence will provide insights into the effectiveness of policies aimed at enhancing digital access and skills, helping to inform future strategies for promoting equitable digital development across the EU. Therefore, calculating sigma convergence will deepen our understanding of whether digital inequality is decreasing among EU countries and will complement the conclusions drawn based on the Gini index (Table 4).

Table 4
σ-convergence of the Digital Development Level of EU Countries

Year	Broadband internet coverage by speed	Broadband internet coverage by technology	Individuals – internet use	Households – level of internet access	Individuals level of digital skills
2013	0.5873	0.3248	0.1614	0.1595	0.4432
2014	0.5250	0.2779	0.1436	0.1380	0.3538
2015	0.5014	0.2514	0.1333	0.1183	0.3078
2016	0.4728	0.2031	0.1198	0.1066	0.3511
2017	0.4178	0.1809	0.1117	0.0976	0.3674
2018	0.3675	0.1503	0.0938	0.0724	0.3796
2019	0.2314	0.1250	0.0849	0.0677	0.4232
2020	0.2005	0.1117	0.0747	0.0542	0.1045
2021	0.1562	0.0968	0.0649	0.0446	0.1487
2022	0.1265	0.0956	0.0496	0.0382	0.1464
2023	0.1165	0.0763	0.0492	0.0328	0.1468

The analysis of variation coefficients for different digital inequality indicators among EU countries demonstrates a general trend towards decreasing variability and, consequently, convergence in these aspects. This indicates a gradual reduction in the digital divide between countries. For example, for the indicator "Broadband internet coverage by speed," the coefficient of variation significantly decreased from 0.5873 in 2013 to 0.1165 in 2023. This suggests that access to high-speed broadband internet is becoming more uniform among EU countries, which is a positive indicator of digital convergence.

The indicator "Broadband internet coverage by technology" also shows a consistent trend of decreasing variability. In 2013, the coefficient of variation was 0.3248, and by 2023, it had decreased to 0.0763. This indicates that EU countries are gradually approaching a similar level of internet technology usage. For the indicator "Individuals – internet use," which measures internet usage levels among the population, there is also a significant reduction in variability from 0.1614 in 2013 to 0.0492 in 2023. This suggests that the differences between countries in internet usage are gradually smoothing out.

The indicator "Households – level of internet access," which assesses the level of internet access in households, shows a similar trend. The coefficient of variation decreased from 0.1595 in 2013 to 0.0328 in 2023, indicating a reduction in inequality in internet access among households in EU countries. Regarding the indicator "Individuals' level of digital skills," the situation is somewhat more complex. Although variability significantly decreased from 0.4432 in 2013 to 0.1045 in 2020, there is a slight increase to 0.1468 in 2023. This may indicate that the development of digital skills is a more complex process, dependent on various factors that could affect the stability of convergence in this aspect.

Overall, the decrease in the coefficients of variation for most indicators suggests a gradual reduction in digital inequality among EU countries. However, the speed and stability of this process vary among countries, which demonstrate different levels of development in specific aspects of digitalization. This indicates the possibility of dividing countries into clusters with varying dynamics of digital development, necessitating further analysis to explore the engagement of populations in these countries in the field of e-governance.

To determine the optimal number of clusters, the "elbow" method was applied, which is based on constructing a graph of the sum of squared distances within clusters (WCSS) for various cluster counts. The goal is to find the inflection point or "elbow" on the graph (Figure 1), where further increasing the number of clusters leads to a minor reduction in WCSS. This point indicates the optimal number of clusters.

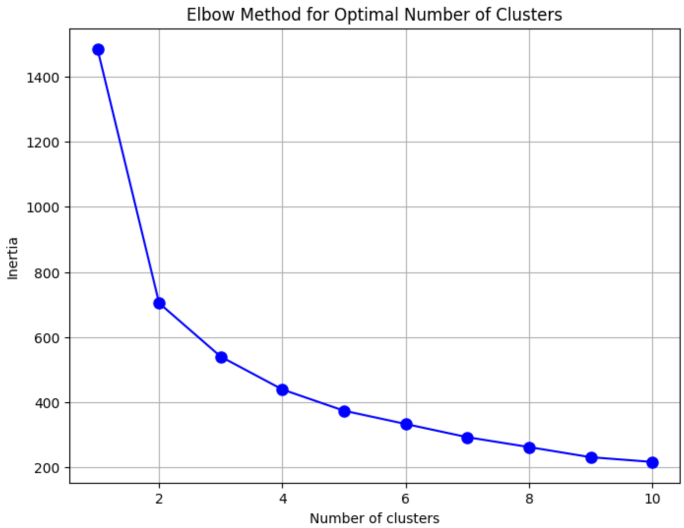

Figure 1: The "Elbow Method" for Determining the Number of Clusters

From Figure 1, we determine that the optimal number of clusters is 2. The clustering of EU countries is based on key indicators such as broadband internet coverage, digital skills, and other relevant digital development metrics. These indicators were derived from trusted data source such as Eurostat [11], ensuring the validity of the analysis. In the next step, clustering was performed using the k-means method, which partitions the data into clusters while minimizing the within-cluster sum of squares. Thus, all EU member states were divided into two clusters based on the intensity of digital technology development and population skills.

To visualize the results of the cluster analysis, the Principal Component Analysis (PCA) method was applied, which reduces multidimensional data to two components for convenience in visualization. PCA allows for the reduction of data dimensions while retaining maximum variation, enabling a clear representation of the data structure and the interactions between different clusters (Figure 2).

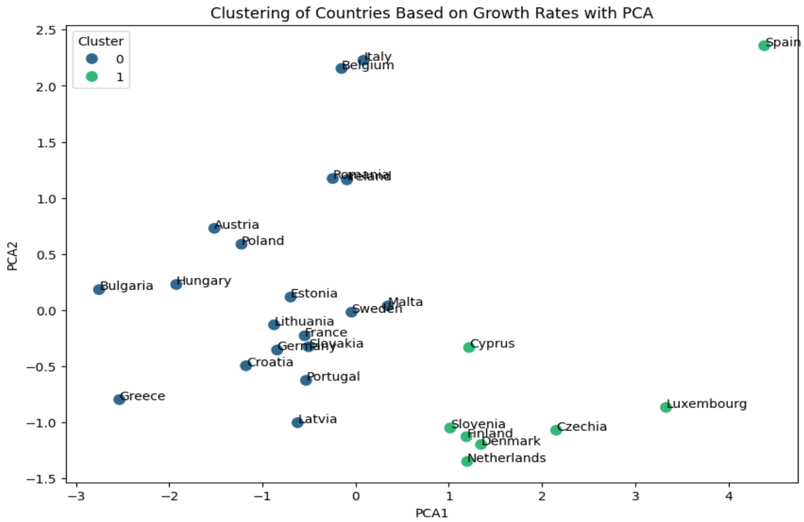

Figure 2: Visualization of Clusters in the Two-Dimensional Space of Principal Components

The member countries of each cluster are presented in Table 5.

Table 5
The Member Countries of Each Cluster

Cluster	Member Countries
0	Austria, Belgium, Bulgaria, Croatia, Estonia, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Malta, Poland, Portugal, Romania, Slovakia, Sweden
1	Cyprus, Czechia, Denmark, Finland, Luxembourg, Netherlands, Slovenia, Spain

Based on the characteristics of each cluster regarding the growth rates of key digital development indicators, several main trends can be identified.

Cluster 0 presents a concerning picture with negative growth rates for broadband internet coverage. This indicates a low level of digital infrastructure development in the countries of this cluster. However, the positive indicator for digital skills (0.20) suggests potential for improvement in digital technology development due to the increasing share of the population acquiring these skills. Countries in this cluster likely have limited resources and investments in digital infrastructure.

In contrast, Cluster 1 demonstrates significantly more positive values for broadband internet coverage, indicating active development of digital infrastructure. This may reflect substantial investments in technology and support from both the government and the private sector. Despite generally positive indicators, the negative value for the population's digital skills (−0.04) underscores the need for further education and training to maximize the benefits of digitalization. This cluster likely comprises countries with more developed economies, where digital technologies are actively integrated into society.

Therefore, the member countries of Cluster 0 need improvements in digital infrastructure, while the member countries of Cluster 1 require enhancements in the digital skills of their populations. This analysis can be useful for formulating policies and development strategies in the field of digital technologies tailored to the needs of the participating countries in each cluster.

The preliminary cluster analysis has revealed important trends in technology development, ensuring the homogeneity of EU countries in the digital space. This research lays the groundwork for further analysis of the impact of digital development indicators on e-governance within each cluster. Specifically, in Cluster 0, inadequate digital infrastructure may hinder the implementation of effective electronic services, whereas in Cluster 1, despite positive internet coverage indicators, the necessity to enhance the digital skills of the population remains crucial for optimizing the use of existing e-government platforms.

Understanding these nuances allows for the formulation of more targeted policies that will promote the development of e-governance in the context of digitalization. This approach highlights the importance of clustering for adapting strategies to the specific needs of countries, which is key to the successful implementation of electronic initiatives at the national level.

4. Results

After clustering countries based on the intensity of digital technology development and the population's skills in this area, a multifactor regression analysis was conducted to assess their impact on user activity in the field of e-governance through websites during the study period. Thus, the factor variables are: Broadband internet coverage by speed, Broadband internet coverage by technology, Individuals – internet use, Households – level of internet access, and Individuals' level of digital skills; the response variable is: E-government activities of individuals via websites.

Let's consider the results of the multifactor regression analysis for Cluster 0 (Figure 3).

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Cluster 0:
                                         OLS Regression Results
==========================================================================================================
Dep. Variable:     E-government activities of individuals via websites   R-squared:                 0.669
Model:                                                             OLS   Adj. R-squared:            0.660
Method:                                                  Least Squares   F-statistic:               81.91
Date:                                                 Tue, 15 Oct 2024   Prob (F-statistic):     8.95e-47
Time:                                                         18:06:33   Log-Likelihood:          -799.54
No. Observations:                                                  209   AIC:                       1611.
Df Residuals:                                                      203   BIC:                       1631.
Df Model:                                                            5
Covariance Type:                                             nonrobust
========================================================================================================
                                          coef    std err          t      P>|t|      [0.025      0.975]
--------------------------------------------------------------------------------------------------------
const                                 -74.3815      9.234     -8.055      0.000     -92.588     -56.175
Broadband internet coverage by speed   -0.1419      0.062     -2.274      0.024      -0.265      -0.019
Broadband internet coverage by technology  -0.0650  0.088     -0.738      0.461      -0.239       0.109
Individuals - internet use              2.9175      0.255     11.451      0.000       2.415       3.420
Households -  level of internet access  -1.2312     0.279     -4.411      0.000      -1.782      -0.681
Individuals level of digital skills     0.0248      0.035      0.713      0.477      -0.044       0.093
==============================================================================
Omnibus:                       56.530   Durbin-Watson:                   2.083
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              125.328
Skew:                          -1.252   Prob(JB):                     6.10e-28
Kurtosis:                       5.850   Cond. No.                     1.89e+03
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Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
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Figure 3: Regression Analysis Results for Cluster 0

The R-squared value of 0.669 indicates that approximately 66.9% of the variation in e-government activities can be explained by the model. The adjusted R-squared value is 0.660, which also confirms the reliability of the model, as it accounts for a significant portion of the data variation. The analysis utilized 209 observations, and the F-statistic is 81.91 with a corresponding p-value of 8.95e-47, demonstrating the statistical significance of the model. This means that the predictors used in the analysis significantly impact the dependent variable.

The constant coefficient is −74.3815, indicating the baseline level of e-government activities when all other variables are held constant. Among the predictors, internet use by citizens emerged as a significant positive influencing factor on e-government activities, with a coefficient of 2.9175 and a p-value of 0.000. This indicates that an increase in internet usage among citizens contributes to higher e-government activities.

In contrast, broadband internet coverage by speed and the level of household internet access showed significant negative coefficients of −0.1419 and −1.2312, respectively, both with p-values less than 0.05. This suggests that greater speed in broadband internet coverage and higher levels of household internet access are associated with lower e-government activities, which may indicate issues related to infrastructure or accessibility in these areas.

On the other hand, broadband internet coverage by technology and the level of digital skills among citizens did not yield statistically significant results, with p-values of 0.461 and 0.477, respectively. This indicates that these factors do not have a significant impact on e-government activities in this cluster.

Overall, the regression analysis highlights the importance of internet use by citizens as a key factor influencing e-government activities, while also revealing potential challenges related to broadband coverage and access levels that need to be addressed to enhance digital government interaction in the member countries of Cluster 0. The model also demonstrates strong statistical fit, confirming the relevance of the selected variables.

Similarly, a multifactor regression analysis was conducted for Cluster 1 (Figure 4).

```
Cluster 1:
                                      OLS Regression Results
=========================================================================================================
Dep. Variable:     E-government activities of individuals via websites   R-squared:                   0.733
Model:                                                           OLS   Adj. R-squared:              0.717
Method:                                                Least Squares   F-statistic:                 44.99
Date:                                               Tue, 15 Oct 2024   Prob (F-statistic):       4.12e-22
Time:                                                       18:06:33   Log-Likelihood:            -319.92
No. Observations:                                                 88   AIC:                         651.8
Df Residuals:                                                     82   BIC:                         666.7
Df Model:                                                          5
Covariance Type:                                           nonrobust
=======================================================================================================
                                            coef    std err          t      P>|t|      [0.025      0.975]
-------------------------------------------------------------------------------------------------------
const                                   -80.4326     14.632     -5.497      0.000    -109.540     -51.325
Broadband internet coverage by speed      0.1318      0.095      1.389      0.169      -0.057       0.321
Broadband internet coverage by technology -0.5252     0.188     -2.790      0.007      -0.900      -0.151
Individuals - internet use                1.6860      0.459      3.669      0.000       0.772       2.600
Households -  level of internet access    0.3481      0.497      0.701      0.485      -0.640       1.336
Individuals level of digital skills      -0.0217      0.035     -0.624      0.535      -0.091       0.048
==============================================================================
Omnibus:                        4.694   Durbin-Watson:                   2.591
Prob(Omnibus):                  0.096   Jarque-Bera (JB):                3.349
Skew:                          -0.330   Prob(JB):                        0.187
Kurtosis:                       2.309   Cond. No.                     2.56e+03
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
```

Figure 4: Regression Analysis Results for Cluster 1

For the regression analysis results for Cluster 1, the R-squared value for this model is 0.733, indicating that approximately 73.3% of the variation in e-government activities can be explained by the chosen predictors. The adjusted R-squared value of 0.717 also confirms that the model is reliable, as it only includes significant variables.

The model utilized 88 observations, and the F-statistic is 44.99 with a corresponding p-value of 4.12e-22, confirming its substantial statistical significance. This indicates that the included predictors have a significant impact on e-government activities.

The constant coefficient is −80.4326, demonstrating the baseline level of e-government activities when all other variables are held constant. One of the key factors positively influencing e-government activities is internet usage by citizens, with a coefficient of 1.6860 and a p-value of 0.000. This confirms that an increase in internet usage among citizens correlates with higher participation in e-government processes.

Conversely, broadband internet coverage by technology showed a negative impact on e-government activities, with a coefficient of −0.5252 and a p-value of 0.007. This suggests that an increase in broadband coverage by technology is associated with a decrease in e-government activities, which may indicate existing issues or barriers in the use of this technology.

The coefficients for broadband internet coverage by speed (0.1318) and the level of household internet access (0.3481) were not statistically significant, with p-values of 0.169 and 0.485, respectively. This confirms that these factors do not have a significant impact on e-government activities in this cluster.

Furthermore, the level of digital skills among citizens did not demonstrate a significant impact on e-government activities, with a coefficient of −0.0217 and a p-value of 0.535. This indicates that the level of digital skills is not a critical factor in this case.

The overall conclusion regarding both clusters emphasizes the importance of internet usage as a key determinant of e-government activities. In Cluster 0, it was found that higher levels of internet usage positively influence e-government activities, while broadband coverage by speed and the level of household internet access showed a negative impact. In Cluster 1, the results highlight a similar trend, where internet usage is an important factor, but broadband coverage by technology proved to be a negative factor. These results indicate potential issues with infrastructure or accessibility that may hinder the development of e-government activities in both clusters, underscoring the need for improvements in conditions for digital interaction between the government and citizens.

5. Conclusions

Digital inequality has serious implications for economic development, innovation, and social cohesion, making an understanding of these aspects crucial for EU countries when adapting their policies. The analysis of digital inequality in European Union countries has demonstrated the importance and complexity of this phenomenon, especially in the context of using e-government services. The research, based on a quantitative approach and utilizing statistical and econometric methods, has enabled a deeper understanding of the key aspects of digital inequality that affect access to public services in the current digital economy.

Selected key indicators, such as broadband internet coverage by speed and technology, the level of internet usage among the population, access to networks, and digital skills, have provided a comprehensive picture of digital inequality in the context of e-governance. The results of descriptive statistics revealed significant discrepancies in the development of digital technologies among EU countries, indicating the presence of social and economic barriers. These barriers reflect the challenges faced by marginalized populations, such as those in rural areas, the elderly, and economically disadvantaged groups, who may not have equal access to the benefits of the digital age.

The analysis of the Gini coefficient has shown positive changes in reducing digital inequality from 2013 to 2023. This indicates a gradual leveling of access to high-speed internet and technologies among EU countries. However, despite positive trends, the level of digital skills remains a problematic area that requires further research and attention. The lack of sufficient skills may limit the use of e-government services, which ultimately hinders social inclusion and economic participation for those without adequate digital proficiency. As technology evolves rapidly, the ability of the population to keep pace with technological changes remains a significant challenge.

The assessment of sigma convergence confirms that the dispersion among countries regarding digital indicators is decreasing, which suggests a gradual leveling of digital development levels. This is a positive sign of progress, but digital literacy and access to advanced digital tools still need to be prioritized. Attention must be given to improving digital skills, as this indicator shows less change in recent years. This highlights the importance of conducting cluster analysis for a deeper understanding of the varying levels of digitization among countries and the need for targeted, tailored interventions.

The application of the elbow method revealed the optimal number of clusters (2), allowing for the distribution of EU member countries into two main groups based on the intensity of digital technology and population skills development. Cluster 0 includes countries with negative growth in broadband internet coverage, indicating a low level of digital infrastructure development. However, the positive indicator of the population's digital skills suggests potential for improvement. Countries in this cluster likely have limited resources for investment in digital infrastructure, yet the skills of their population provide an opportunity for overcoming some of these barriers. Cluster 1 demonstrates positive results in broadband internet coverage, indicating active development of digital infrastructure. These countries are likely attracting significant investments in technology and are making strides in closing the digital divide. However, the need to enhance the population's digital skills points to challenges related to education and upskilling. This reflects the growing realization that digital infrastructure alone is not enough to guarantee full participation in the digital economy. Investment in education and lifelong learning programs is critical for enhancing the workforce's digital capabilities and bridging the digital skills gap.

The results of multifactor regression analysis for both clusters demonstrate important features of the impact of digitization on e-government activities. In Cluster 0, it is observed that a key factor is the population's internet usage, which has a significant positive effect on participation in e-government processes. However, despite positive trends in digital skills, the negative values of broadband internet coverage and household access levels indicate serious infrastructural challenges that may hinder the effective implementation of electronic services. This points to the need for investment in improving digital infrastructure to ensure better access to e-government services and enhance the digital inclusion of citizens. In Cluster 1, while internet usage is also an important factor, the results indicate a negative impact from broadband internet coverage by technology. This may suggest a need for further optimization of existing infrastructural solutions to maximize the potential of e-government. Further research should explore how emerging technologies such as 5G, IoT, and AI can be integrated into e-governance to boost the efficiency and accessibility of digital services. Overall, the analysis reveals that countries in Cluster 0 need improvements in digital infrastructure, while countries in Cluster 1 have aspirations for developing the population's digital skills. The importance of the results obtained lies in the opportunity to form targeted strategies to support digitization and e-governance, tailored to the specific needs of each cluster. By investing in infrastructure in Cluster 0 and focusing on education and skill-building in Cluster 1, EU countries can foster a more inclusive and prosperous digital economy.

As a result of the analysis conducted, it has become evident that digital inequality in European Union countries is a complex and multifaceted phenomenon that requires careful consideration. Despite positive trends in reducing digital inequality, the identified disparities in the development of digital technologies and population skills highlight the importance of adapting policies aimed at improving access to e-government services. Cluster analysis underscored that countries facing serious infrastructural challenges should be prioritized for attracting investment to develop digital infrastructure. At the same time, countries with positive dynamics in digitization need to focus on enhancing the digital skills of their populations through targeted educational programs and lifelong learning initiatives.

Thus, a strategic approach to developing the digital economy, oriented toward the specific needs of each cluster, can significantly contribute to economic growth and social cohesion in the EU while ensuring the effective implementation of electronic government services to improve citizens' quality of life. This approach will also help to ensure that no country or individual is left behind in the digital transformation, and that the potential of digital technologies is fully realized for the benefit of all EU citizens.

Declaration on Generative AI

The author has not employed any Generative AI tools.

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