Relations between Development of E-Government and Government Effectiveness, Control of Corruption and Rule of Law in 2010–2020: a Cluster Analysis

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Abstract

Nowadays, an increasing number of citizens use information and communication technologies to interact with the government, and therefore it is necessary for the public sphere to constantly innovate and meet the expectations placed on it under the pressure of an ever-changing environment. The aim of the article is to compare the progress of e-government between 2010 and 2020 in the member states of the European Union based on selected global indices of e-government development. The article examines the relationship between the E-Government Development Index (EGDI) and selected indices within the Worldwide Governance Indicators. The goal of the article is achieved through correlation and cluster analysis. The results of these countries vary from state to state. It was found that according to the level of digitization of public administration and the quality of public services, EU countries can be divided into 5 groups. However, within the monitored period, the EU states achieved progress in the field of digitization and the quality of public administration. The average value of EGDI increased by about 34% between 2010 and 2022 and the share of countries at a very high level EGDI in 2010 was approx. 11% and in 2022 even 100%. The best results in this area are achieved by the states in the north of the EU (for example, Denmark, Finland and Sweden), on the contrary, the worst results are achieved by the states in the east of the EU (for example, Bulgaria and Romania). The results also showed that countries that were in the best cluster and the worst cluster in individual years are still in those clusters.

Keywords

digitization, governance indicators, cluster analysis, e-government development index, European Union countries, public administration

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Introduction

The aim of the European Union in the framework of the digital transformation of Europe is to ensure that 100% of services are provided to citizens in a digital form in the field of public administration. As part of electronic healthcare, 100% of citizens will also have access to medical records. 80% should be able to log in via digital identity (European Commission, 2023).

The significant development of information and communication technologies (ICT) changes current standards in all areas and their use leads to the emergence of the so-called information society. The information society is characterized by certain characteristics, such as the ability to access information; the subject is at the same time a means in the communication process; processes take place virtually, for example communication between public administration bodies Szewczyk (2021).

ICT provides access to information through the Internet, wireless networks, mobile phones, computers, etc. ICT also provides online services and applications. Their use has a number of advantages and disadvantages, see more in Bosamia (2013).

Public administrations are increasingly using ICT-based means to communicate with subjects (for example, in the case of electronic filing of tax returns) Hamza et al (2021). Governments are introducing new and new information systems to meet the needs of citizens. However, their implementation is often not optimal Sanda, MacDonald & Ferrer (2019). According to Krishnan, Teo & Lim (2013), a high level of e-government has an impact on the economic prosperity of a country. At the same time, citizens are expected to be part of the strategic decision-making process of the government through e-government Bindu, Prem Sankar & Satheesh Kuma (2019).

E-government uses information and communication technologies to provide public services at all levels, both local and national Carter, Yoon & Liu (2022). It empowers citizens by improving human capital, making ICT accessible to citizens, and improving and increasing connectivity between government and citizens through digital public services (Silal, Jha, & Saha, 2023).

Among the main principles based on which the provision of public services through e-government should take place include transparency in the provision of public services; access to public services for all subjects; the efficiency of the use of public funds; protection of confidentiality of personal data; availability of public services Andronicean & Georgescu (2021).

The goal of the European Union is for all state services to be provided digitally by 2030. Currently (year 2022), more than 80% of government services are available digitally European Commission (2022). However, several challenges related to e-governance need to be resolved by 2030. for example: economic, technological and social challenges and legal/regulatory, institutional/operational/environmental, political, financial, qualitative, processual, structural, organizational, development, technical, managerial, contextual, political and training, data and information, interested, etc. Arshad & Asghar (2020).

The presented article is structured in 5 parts. The introduction is followed by an overview of research studies and their conclusions regarding e-government. The next part

is devoted to the characteristics of the data and methods used in the empirical part. In the application part, the EU states are grouped into clusters through correlation and cluster analysis. The individual results of the article are summarized in the discussion and conclusion, including limits and possibilities for future research.

1 Literature review

E-government is a term that represents the use of ICT in public administration. E-government can represent the use of such tools through ICT that lead to the provision of more efficient public services to entities. Another definition of e-Government is focused on the implementation of ICT by public administration bodies with the aim of transforming the relations between all subjects that participate in this process Lehner (2013). E-government represents an effective tool that connects all entities that are involved in this process and thus replaces traditional public services Fan et al. (2022).

E-government includes the general process of digitization of the public sector. In addition to the network infrastructure itself, e-government also includes the entire infrastructure of the authorities. E-Government can ensure the use of wider public services and reduce bureaucracy for all subjects, not only in the European Union. E-government can be used to improve the transparency of the administrative system Androniceanu & Georgescu (2021). E-government does not only involve certain technologies but also rules and procedures. E-government thus functions within the framework of the rule of law, and general rules are protected at the same time, such as the protection of the rights of all subjects Eger & Maggipinto (2009). The rule of law thus represents an important link in the development of e-government.

For e-government services to be provided effectively, it is necessary to ensure their quality, as this affects the satisfaction of end users and thus the entire system. In addition to high-quality and reliable public services, entities require security and simplicity along with usefulness when using them (Mingyue et al., 2022). The success of e-government also depends on the trust of citizens in the government itself.

It is advisable for states not only of the European Union to invest in their e-government services and to try to maintain or increase the trust of subjects within their political measures Pérez-Morote, Pontones-Rosa & Núñez-Chicharro (2020). The reason is, among other things, that the number of users of services is increasing and they are creating new requirements that satisfy their needs and thus expectations from new ICTs are also growing (Shouran, Priyambodo and Rokhman, 2019).

According to several research for example Srivastava & Teo (2007), there is a positive relationship between the level of e-government and the efficiency of public administration. The performance of public administration and the level of e-government are interrelated, but the dynamics of these parameters is caused by other indicators, according to research by Dobrolyubova, Klochkova & Alexandrov (2019). If e-government and government efficiency are correlated, they can represent a tool for influencing corruption Kim (2014).

According to a study by Garcia-Murillo (2013), e-government influences reducing corruption in the country. Also, for example, in Park & Kim (2019); Shim & Eom (2009).

Also, according to Mistry & Jalal (2012), e-government and thus an increase in spending in this area leads to a reduction in corruption in the country, especially in developing countries. The use of ICT by governments is currently essential to the effectiveness of government. Corruption is the abuse of public power for private gain and usually occurs in situations where the public and private sectors collide. In situations where a public entity must transfer revenues or costs to the private sector, the probability of bribery arises. At the same time, however, e-government can lead to the emergence of new types of corruption Adam & Alhassan (2021). The use of ICT creates a more transparent system and increases the accountability of public administration bodies and elected politicians for their performance. By reducing physical contact, ICTs reduce undue bargaining and abuse. Government systems can be more transparent and allow subjects to access government data more easily Zheng (2016). The positive impact of e-government on corruption is also mentioned by Kim (2014).

E-government, focused on the interested entities themselves, leads to the fact that citizens cooperate more effectively with the government. Adherence to the rule of law leads to the development of the given state and, through e-government, to the control of possible corruption, thereby increasing the effectiveness of the government. E-government helps government address the needs and wants of citizens Agbozo & Asamoah (2019).

Government effectiveness includes the quality and scope of services provided, policy formulation and implementation. The effectiveness and efficiency of the government varies in different states, for example, according to the number of citizens or according to political stability. For the optimal use of e-government, it is necessary to ensure a suitable infrastructure and the skills of all interested subjects Dobrolyubova, Klochkova & Alexandrov (2019). Likewise, E-government itself varies in different countries Hodžić, Ravšelj & Alibegović (2021).

The goal of e-government is to provide public services by reducing bureaucracy in their use. This will build trust in the actions of the government. It is appropriate for e-government that its services are aimed directly at the citizen (not only at the infrastructure itself), because if these services are accepted and optimally implemented, they can increase the efficiency of public services. For e-government to function optimally, various factors such as: citizen satisfaction, security, government support and initiative, required ICT skills, efficiency, innovative thinking, rule of law, availability of ICT infrastructure and ICT equipment need to be positively influenced.

For the development of e-government, governments need to develop ICT initiatives and increase the digital skills of citizens. ICT is currently a trend that is one of the important means that lead to success, both in the private and public sectors. For that reason, the availability, access and use of ICT is a tool for the effectiveness of e-government, and it is therefore appropriate that EU states ensure this for their citizens.

Public authorities using ICT can be more effective in implementing their policies. For citizens to have access to ICT, they need to be equipped with the necessary technologies that they will use to access public information and to interact more effectively with public administration bodies. A higher level of e-government thus represents a tool for transparency with lower corruption in the state.

Government efficiency will ensure a higher level of e-government Adam & Alhassan (2021). Countries that do not use ICT at all levels of the economy, including public administration, will not be able to compete in these areas in the future. The reconstruction of public administrations towards the use of ICT is essential and should become a long-term permanent concern of governments Androniceanu & Georgescu (2022).

ICT can be used within all interested entities. Government to Government (G2G) represents relationships between public institutions. Government and Civil Servants (G2E) represents the relationship between government and government employees. Government to Citizens (G2C) enables the exchange of information between government and citizens. Government and business (G2B) represent the relationship between government and business, mainly in the field of public procurement, etc. Androniceanu & Georgescu (2021).

E-government implementation is not always successful, especially in developing countries. For example, Furuholt & Wahid (2008) found that about 60% of e-government initiatives in developing countries did not meet the desired results.

According to Pérez-Morote, Pontones-Rosa & Núñez-Chicharro (2020), a higher level of citizen trust leads to a greater use of e-government, but its use cannot prevent a decrease in trust. At the same time, the growth of investments in e-government leads to the growth of the use of e-government. At the same time, differences between countries were found to be due to digital skills, income and education, based on the division of EU countries into 3 clusters.

2 Research methods

The aim of the article is to compare the progress of e-government between 2010 and 2020 in the member states of the European Union based on selected global indices of e-government development. The purpose of the article is to find out whether the position of the state's changes in the monitored years or not. The assumption is that the EU states show internally homogeneous elements and are externally heterogeneous, which makes it possible to create groups of countries.

The article draws on the literature that deals with e-government mainly in the countries of the European Union. The empirical part uses data and selected indicators from the United Nations and the World Bank.

The selected set consists of 27 countries of the European Union, namely: Austria; Belgium; Bulgaria; Croatia; Cyprus; Czechia; Denmark; Estonia; Finland; France; Germany; Greece; Hungary; Ireland; Italy; Latvia; Lithuania; Luxembourg; Malta; Netherlands; Poland; Portugal; Romania; Spain; Slovakia; Slovenia; Sweden.

The empirical analysis was carried out for the period 2010–2020. The year 2020 is the last year for which all values of the selected indicators are available.

The level of government digitization is measured through the E-Government Development Index (EGDI). The e-Government Development Index (EGDI) looks at the

level of e-Government in the countries of the United Nations. It is an indicator that consists of three areas, namely the provision of online e-government services, telecommunication connectivity dealing with the quality and availability of the Internet, and human capacity dealing with literacy and education. Its values range from 0 to 1, while: 0.75–1 means very high values; 0.5–0.7499 means high values; 0.25–0.499 means medium values; 0–0.2499 indicates low values. Government effectiveness (GE), Control of corruption (CC) and Rule of Law (RL) are used to evaluate the quality of public administration. Their index reaches 0–100 and the larger the value, the more effective this indicator is, see Table 1.

Table 1: Definition of variables

Indicators	Definition	Unit	Source
E-Government Development Index (EGDI)	It represents the status of e-government level including online service delivery, telecommunication connectivity and human capacity	Index (0–1)	United Nations
Government effectiveness (GE)	It represents the perception of the quality of public services, the civil service and its degree of independence, the quality of policy formulation and implementation, and the credibility of the government's commitment to that policy	Index (1–100)	World Bank
Control of corruption (CC)	Represents the perception of how public power is used for private purposes, including corruption and interest groups and their influence on public power	Index (1–100)	World Bank
Rule of Law (RL)	It represents the perception in which subjects trust the rules and how they comply with them, including the quality of enforcement of contracts, property rights, etc.	Index (1–100)	World Bank

Source: United Unions (2023); World Bank (2023), own processing

The evaluation of selected indicators in EU countries for the period 2010–2020 is carried out using correlation analysis and hierarchical cluster analysis.

Correlation analysis is used to assess the degree of relationship between the selected indices, see the formula (1):

$$r = \frac{\sum_{i=1}^{n}(x_i - x)\,(y_i - y)}{\sqrt{\sum_{i=1}^{n}(x_i - x)^2 \; \sum_{i=1}^{n}(y_i - y)^2}} \tag{1}$$

where: r represents Pearson's correlation coefficient, x_i a y_i represent the values of x and y for the ith individual (Mukaka, 2012). The significance level is chosen at 5%.

Through cluster analysis, objects (in this case countries) are divided into clusters based on their similarities. Individual clusters are more like each other than other clusters (Frades & Matthiesen, 2010). It is a method that uses multidimensional and quantitative measurements to group objects according to similar properties (Jaeger & Banks, 2022). A cluster is an object whose distance is smaller than the distance shown by objects that do not belong to the given cluster.

Clustering is done through hierarchical clustering, which is done by dividing larger clusters and it is not necessary to know the number of clusters in advance with this method. This method makes it possible to create a so-called dendrogram, which shows how the clusters are related to each other. Ward's method was chosen as the clustering method, which uses the analysis of variance approach to evaluate the distances between clusters. Through this method, the sum of squares of any two clusters that can be formed at each step is minimized. The disadvantage of this method is that it creates clusters with a small number (Frades & Matthiesen, 2010). Ward's method uses the Euclidean distance defined by the formula (2):

$$d_{ij} = \sqrt{\sum_{k=1}^{n} \left(x_{ik} - x_{jk}\right)^2}, \tag{2}$$

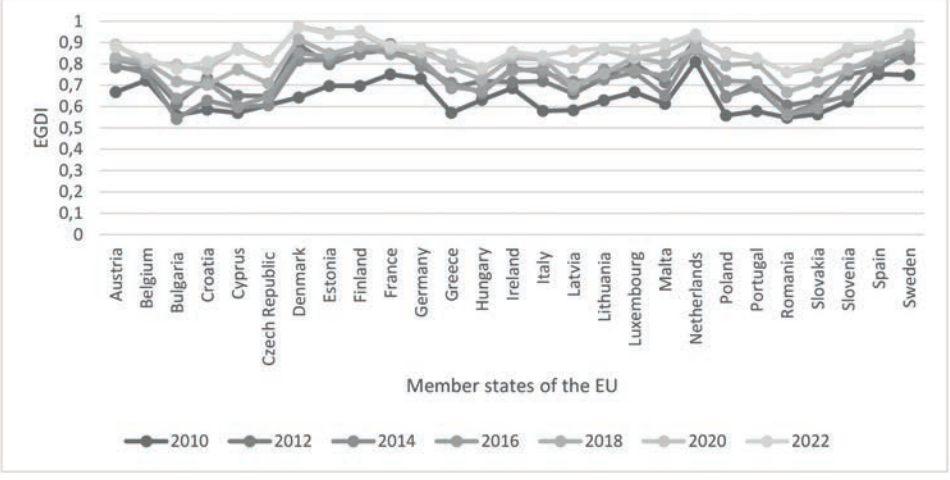
where: x_{ik} is the value of k variable for $i-th$ object and x_{jk} is the value of k variable for $j-th$ object (Frades & Matthiesen (2010); Everitt (2011).

All the calculations and outputs of the analysis were generated in the IBM SPSS Statistics program.

3 Solutions and Results

The development of the EGDI index can be seen in Figure 1.

Figure 1: The progress of the EGDI between the years 2010–2022

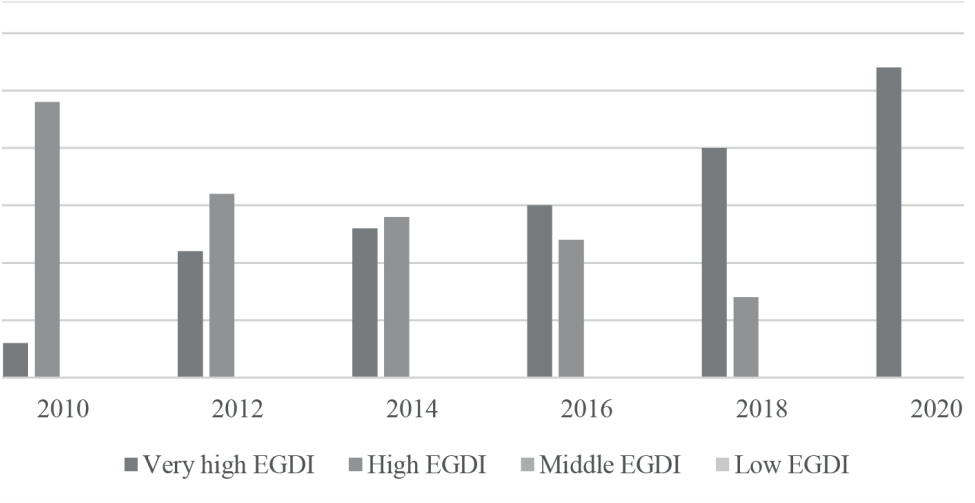


Source: United Nation (2023)

The average value of EGDI increased by about 34% between 2010 and 2022 and the range of variation decreased by about 18%, which may indicate that the differences between EU countries have decreased over the years. The average EGDI value in 2010 was 0.64, in 2012 it was 0.74, in 2014 it was 0.72, in 2016 it was 0.75, in 2018 it was 0.8 and in 2020 it was 0.85. The countries that do not reach the average value are mainly from Southern, Eastern and some Central European countries. On the contrary, the states that achieve higher than average levels are mainly states in the north and west of the European Union.

Based on the EGDI, countries are classified according to the level of e-government development: very high, EGDI > 0.75; high, 0.50 < EGDI < 0.75; medium, 0.25 < EGDI < 0.50; low, EGDI < 0.25 Yerina, Demydiuk & Demydiuk (2021). Figure 2 shows the distribution of the number of countries according to their achieved EGDI values.

Figure 2: Distribution of countries according to EGDI in the years 2010–2020



Source: United Nation (2023)

As can be seen, every year there was an increase in the number of countries moving from a high level to a very high level. The share of countries at a very high level in 2010 was approx. 11%, in 2012 approx. 41%, in 2014 approx. 48%, in 2016 approx. 56%, in 2018 approx. 74% and in 2022 even 100%. According to Yerin, Demydiuk & Demydiuk (2021), the reasons for these shifts were investments in ICT infrastructure and the transformation of public services into digital services..

3.1 Correlation of variables

A correlation analysis was performed to identify the correlation between selected indicators that characterize the level of public administration and its digitization. The results of the correlation analysis in individual years can be seen in Table 2.

Through the correlation analysis, a strong positive correlation was found with all the selected indicators that characterize the level of public administration and EGDI. These indicators show a statistically significant correlation with EGDI.

Table 2: Correlation analysis between EGDI, GE, CC and RL in 2010. 2012, 2014, 2016, 2018 and 2020

2010	**EGDI**	**GE**	**CC**	**RL**
EGDI	1	0.690	0.784	0.744
GE	0.690	1	0.948	0.951
CC	0.784	0.948	1	0.958
RL	0.744	0.951	0.958	1
2012	**EGDI**	**GE**	**CC**	**RL**
EGDI	1	0.774	0.814	0.767
GE	0.774	1	0.964	0.949
CC	0.814	0.964	1	0.965
RL	0.767	0.949	0.965	1
2014	**EGDI**	**GE**	**CC**	**RL**
EGDI	1	0.767	0.732	0.731
GE	0.767	1	0.939	0.954
CC	0.732	0.939	1	0.965
RL	0.731	0.954	0.965	1
2016	**EGDI**	**GE**	**CC**	**RL**
EGDI	1	0.783	0.772	0.711
GE	0.783	1	0.937	0.934
CC	0.772	0.937	1	0.939
RL	0.711	0.934	0.939	1
2018	**EGDI**	**GE**	**CC**	**RL**
EGDI	1	0.783	0.859	0.704
GE	0.783	1	0.943	0.927
CC	0.859	0.943	1	0.918
RL	0.704	0.927	0.918	1
2020	**EGDI**	**GE**	**CC**	**RL**
EGDI	1	0.716	0.730	0.677
GE	0.716	1	0.913	0.921
CC	0.730	0.913	1	0.937
RL	0.677	0.921	0.937	1

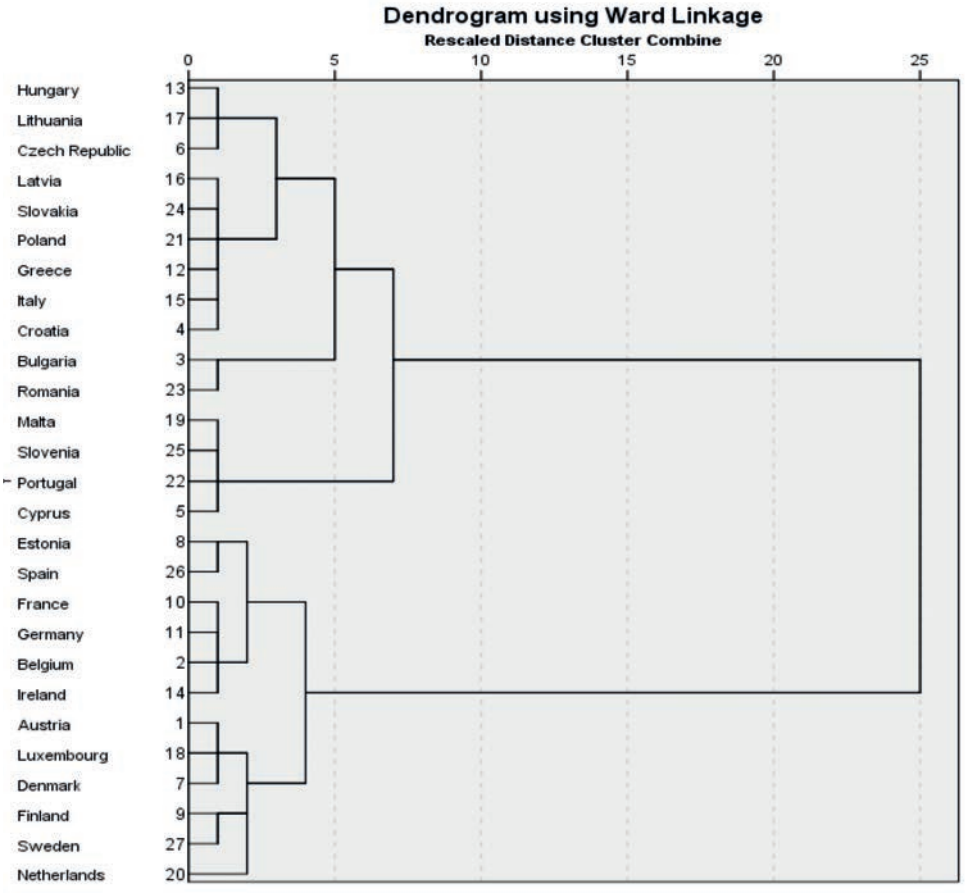
Source: own processing

The strongest correlation is mainly between EGDI and government effectiveness and corruption control, which corresponds to other research that was mentioned in the theoretical background. There is therefore a statistically significant positive correlation between government digitization and public administration performance.

3.2 Evaluation of the Similarities of EU Countries using Hierarchical Cluster Analysis

Hierarchical cluster analysis was used to create clusters of EU countries. EGDI, GE, CC, RL indices were used as inputs for hierarchical cluster analysis. Through cluster analysis, all 27 EU states were divided into groups characterized by similar behaviours according to the indices. The result of the hierarchical clustering process is displayed in individual years through a dendrogram (Figure 3–8), according to which the probable number of clusters can be deduced. Average cluster values can be seen in tables 3–8.

Figure 3: Dendrogram of Similarities in EU Countries in 2010



Source: own processing

The dendrogram shows the possible division of states into 5 clusters.

Cluster 1 comprises six countries (Austria, Denmark, Finland, Luxembourg, Netherlands, Sweden). These are the states that are characterized by the highest average level of GE, CC and RL and a very high level of EGDI. The greatest similarity can be found between all states within these indicators. Further between Austria, Luxembourg, Denmark and Finland in the EGDI indicator. The Netherlands and Sweden exceed the average value of EGDI within this cluster.

Cluster 2 comprises six countries (Belgium, Estonia, France, Germany, Ireland, Spain). These are the states that are characterized by the highest average level of EGDI and a very high level of GE, CC and RL. The greatest similarity can be found between France, Ireland, Germany and Belgium in the areas of GE, CC and RL, and further between Estonia and Spain. In the EGDI, there is the greatest similarity between Belgium, France, Germany and Spain, and also between Estonia and Ireland.

Cluster 3 comprises two countries (Bulgaria, Romania). This is a cluster characterized by the worst values in all indicators.

Cluster 4 comprises eight countries (Croatia, Czech Republic, Greece, Hungary, Italy, Latvia, Lithuania, Poland, Slovakia). After the previous cluster, these are the countries with the second worst EGDI level. Croatia, Greece and Italy show the most similar characteristics in GE. Within this indicator, the Czech Republic and Slovakia show above-average values. Latvia, Italy, Hungary and Slovakia have similar characteristics in CC. In contrast, Poland shows above-average values in this area. Hungary, Latvia and Lithuania are similar in the area of RL. On the contrary, the Czech Republic shows an above-average value compared to the average of the cluster. Croatia, the Czech Republic and Latvia are most similar in EGDI.

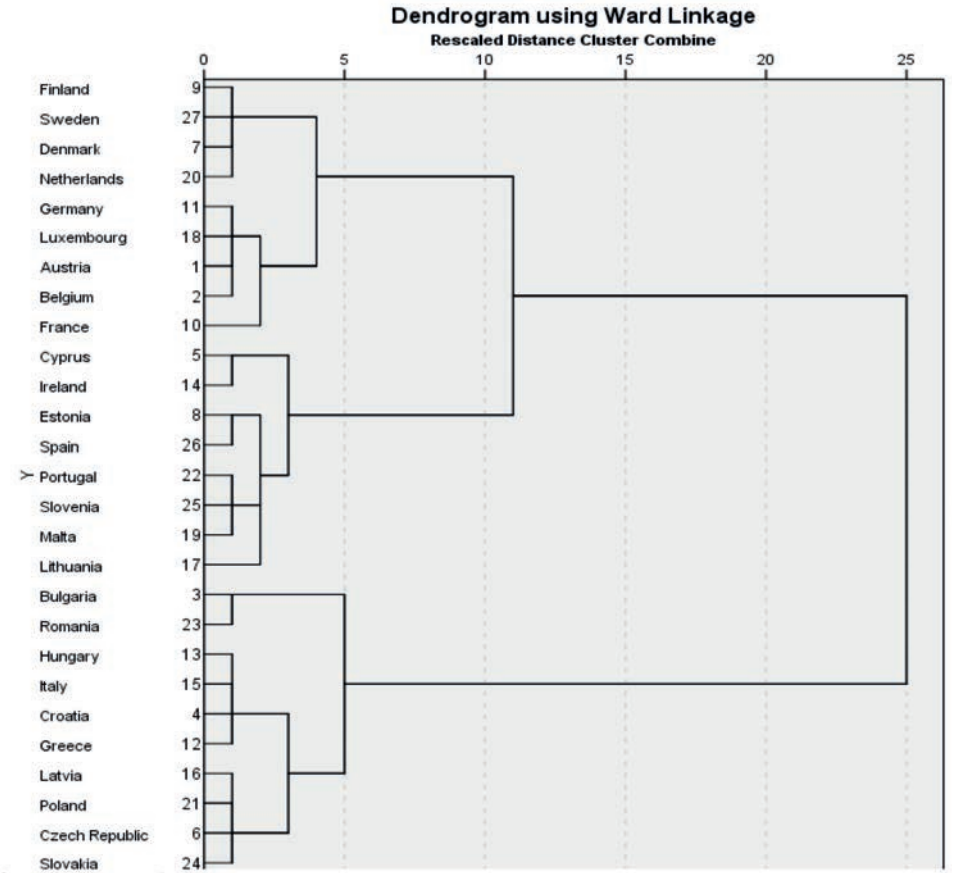
Cluster 5 comprises four countries (Cyprus, Malta, Portugal, Slovenia). These are states that are characterized by high values in GE, CC and RL and rather low values in EGDI. Portugal and Slovenia have the highest similarities in GE, CC and RL. Conversely, Portugal and Cyprus are similar in EGDI.

Table 3: Average cluster values in 2010

Cluster	EGDI	GE	CC	RL
1. cluster	0.71	97.29	97.06	98.34
2. cluster	0.72	86.76	88.57	89.97
3. cluster	0.55	52.87	48.57	54.98
4. cluster	0.59	72.04	64.55	68.72
5. cluster	0.60	83.85	78.81	85.19

Source: own processing

Figure 4: Dendrogram of Similarities in EU Countries in 2012



Source: own processing

The dendrogram shows the possible division of states into 5 clusters.

Cluster 1 comprises five countries (Austria, Belgium, France, Germany, Luxembourg). This is a cluster characterized by the second highest average values in all indicators. In the field of GE, Austria, Belgium and Germany are most similar. In CC, all countries are the most similar except for the Netherlands, which shows above-average values. Belgium, France and Germany as well as Austria and Luxembourg are most similar in RL. In the EGDI, Austria and Belgium are most similar, followed by Germany and Luxembourg.

Cluster 2 comprises two countries (Bulgaria, Romania). This is a cluster characterized by the worst values in all indicators.

Cluster 3 comprises eight countries (Croatia, Czech Republic, Greece, Hungary, Italy, Latvia, Poland, Slovakia). The Czech Republic, Latvia and Slovakia are most similar in GE, followed by Croatia, Hungary and Poland. In Area CC, the Czech Republic, Hungary and Latvia are most similar, as well as Slovakia and Croatia. The most similar in RL

are Latvia and Poland and then Greece with Italy and Slovakia. The most similar in EGDI are Hungary, Croatia and Italy, followed by the Czech Republic, Latvia, Poland and Slovakia.

Cluster 4 comprises eight countries (Cyprus, Estonia, Ireland, Lithuania, Malta, Portugal, Slovenia, Spain). These are the countries with the third highest values in all indicators. Slovenia, Spain and Portugal are the most similar in GE. Estonia and Portugal are most similar in CC. The most similar in RL are Cyprus, Estonia, Spain and Portugal. In the EGDI, Estonia and Spain are most similar, followed by Ireland, Lithuania, Portugal and Slovenia. In GE, CC and RL areas, Ireland achieves above average values and in EGDI it is Estonia.

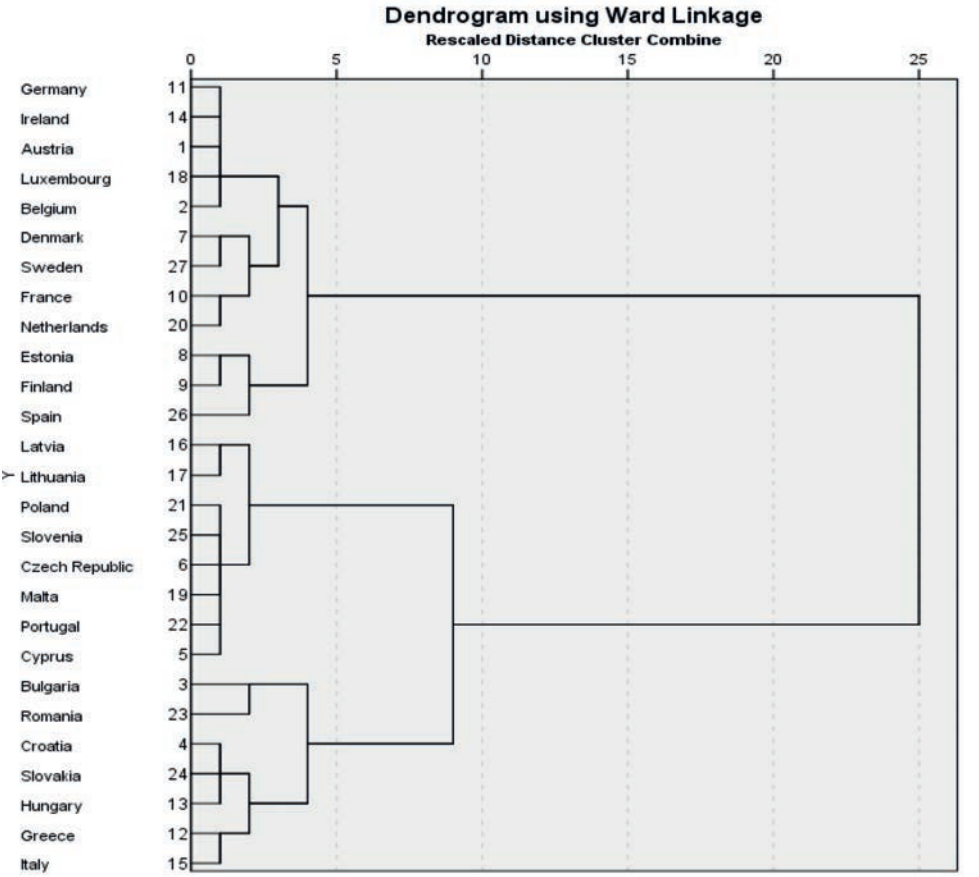
Cluster 5 comprises four countries (Denmark, Finland, Netherlands, Sweden). This is the best cluster with the highest values. All states are similar in all indicators.

Table 4: Average cluster values in 2012

Cluster	EGDI	GE	CC	RL
1. cluster	0.81	92.32	92.51	93.15
2. cluster	0.61	52.13	46.68	54.69
3. cluster	0.68	70.73	62.74	68.31
4. cluster	0.73	82.35	80.39	84.27
5. cluster	0.88	98.70	98.34	98.47

Source: own processing

Figure 5: Dendrogram of Similarities in EU Countries in 2014



Source: own processing

The dendrogram shows the possible division of states into 5 clusters.

Cluster 1 comprises nine countries (Austria, Belgium, Denmark, France, Germany, Ireland, Luxembourg, Netherlands, Sweden). These states are characterized by the highest values in GE, CC and RL and very high values in EGDI. The greatest similarity in GE is between Austria, Belgium, Germany, Ireland and Luxembourg, and further between Denmark, France, the Netherlands and Sweden. The greatest similarity in CC is between Austria, Belgium, Germany and Ireland, and further between Denmark, France, Luxembourg, the Netherlands and Sweden. In RL, the greatest similarity is between Austria, Luxembourg, France, the Netherlands and Sweden. The greatest similarity in EGDI is reported in Germany, Ireland and Luxembourg, and further between Austria, Denmark and Sweden. Cluster 2 comprises two countries (Bulgaria, Romania). This is a cluster characterized by the worst values in all indicators.

Cluster 3 comprises five countries (Croatia, Greece, Hungary, Italy, Slovakia). This is the cluster that is the second worst in GE, CC and RL. In GE and CC, the greatest similarities are between Croatia, Hungary and Slovakia. In RL, the greatest similarities are between Italy, Slovakia and Greece.

Cluster 4 comprises eight countries (Cyprus, Czech Republic, Latvia, Lithuania, Malta, Poland, Portugal, Slovenia). These are the states that are the second worst in the EGDI. Within GE, all countries except Poland are the most similar. In CC, the most similar states are the Czech Republic and Latvia, followed by Poland, Slovenia and Lithuania, and finally Malta and Portugal. Cyprus, the Czech Republic, Malta and Portugal are most similar in RL, as well as Slovenia, Poland, Latvia and Lithuania. In the EGDI, Cyprus, the Czech Republic, followed by Latvia and Lithuania and finally Malta, Poland and Slovenia are most similar.

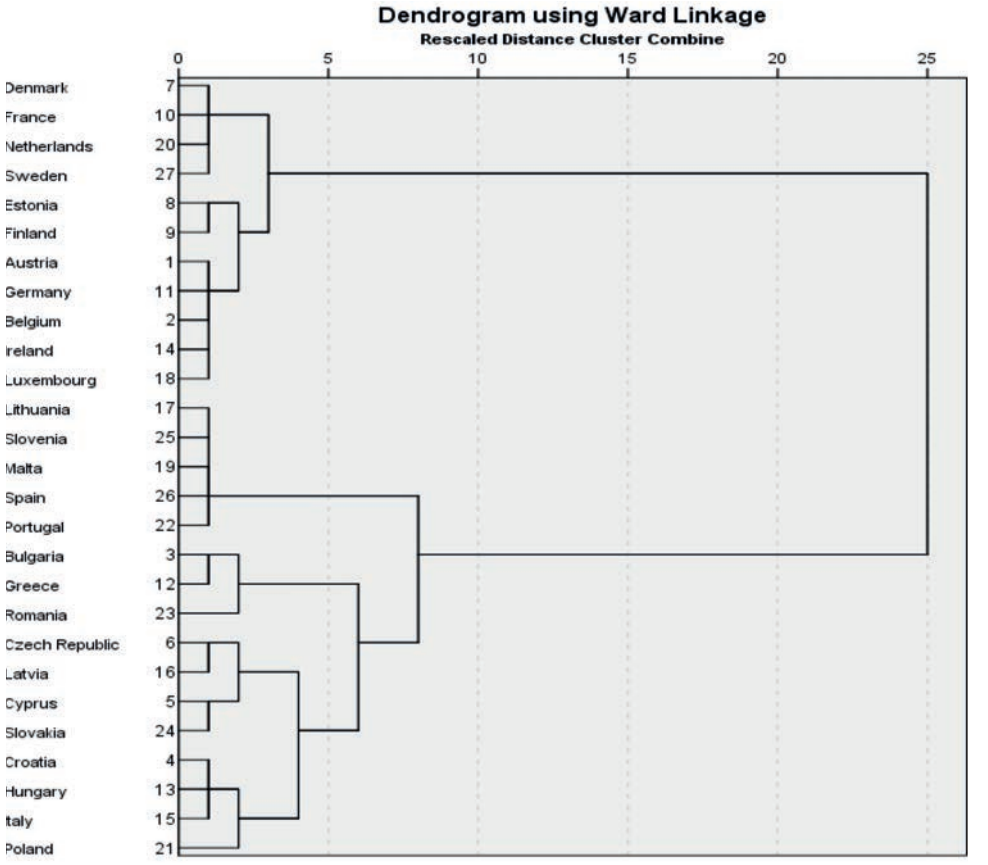
Cluster 5 comprises three countries (Estonia, Finland, Spain). These states are characterized by the largest level of EGDI and very high values in the other indicators.

Table 5: Average cluster values in 2014

Cluster	EGDI	GE	CC	RL
1. cluster	0.81	94.28	95.25	95.78
2. cluster	0.55	55.53	49.76	59.62
3. cluster	0.68	71.35	58.65	67.5
4. cluster	0.66	79.57	73.92	81.67
5. cluster	0.83	84.62	82.85	85.26

Source: own processing

Figure 6: Dendrogram of Similarities in EU Countries in 2016



Source: own processing

The dendrogram shows the possible division of states into 5 clusters.

Cluster 1 comprises eleven countries (Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Ireland, Luxembourg, Netherlands, Sweden). These are the states that are characterized by the greatest level in all indicators. In GE, the most similar countries are Austria, Belgium, Finland and Ireland, followed by Denmark, France and the Netherlands, and finally Germany, Luxembourg and Sweden. Within the CC, Austria, Belgium, Ireland, Finland and Estonia are most similar, followed by Denmark, France, Luxembourg and Sweden. In RL, Austria, Denmark, France, the Netherlands and Sweden are the most similar, followed by Estonia, Finland, Belgium and Ireland. In the EGDI, Finland, Sweden and the Netherlands are most similar, followed by Estonia, Denmark, Austria, Germany and France.

Cluster 2 comprises three countries (Bulgaria, Greece, Romania). This is a cluster characterized by the worst values in all indicators.

Cluster 3 comprises four countries (Croatia, Italy, Hungary, Poland). These are the states with the second lowest values in GE, CC and RL indicators. In GE, Croatia and Hungary are most similar, followed by Italy and Poland. Croatia, Hungary and Italy show the most similar characteristics in CC and RL. Croatia and Poland are most similar in EGDI.

Cluster 4 comprises four countries (Cyprus, Czech Republic, Latvia, Slovakia). These are the states that are the second worst in the EGDI. The greatest similarities in GE are between all states. In CC it is the Czech Republic, Latvia and Slovakia. In RL, the Czech Republic and Latvia are most similar, followed by Cyprus and Slovakia. Slovakia and Cyprus are most similar within the EGDI.

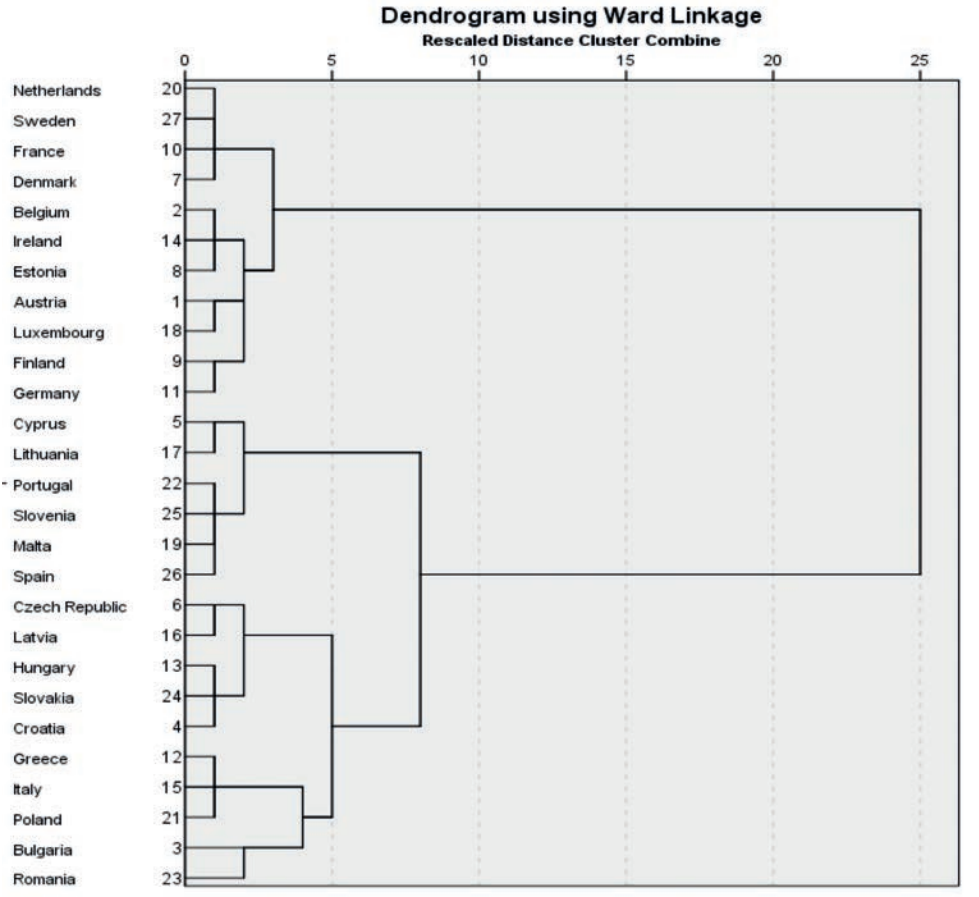
Cluster 5 comprises five countries (Lithuania, Malta, Portugal, Slovenia, Spain). After cluster 1, it is the group of countries with the best values in all indicators. Except for Malta, these states are most similar in GE. A great similarity is also reported in CC (except for Spain). In RL, all states are very similar. Lithuania and Slovenia are most similar in EGDI.

Table 6: Average cluster values in 2016

Cluster	EGDI	GE	CC	RL
1. cluster	0.83	92.70	94.32	93.71
2. cluster	0.63	56.09	52.4	58.97
3. cluster	0.72	70.91	65.26	66.35
4. cluster	0.63	78	69.11	77.76
5. cluster	0.76	82.4	75.29	82.69

Source: own processing

Figure 7: Dendrogram of Similarities in EU Countries in 2018



Source: own processing

The dendrogram shows the possible division of states into 5 clusters.

Cluster 1 comprises eleven countries (Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Ireland, Luxembourg, Netherlands, Sweden). These are the states that are characterized by the greatest level in all indicators. The most similar countries in GE are Austria, Belgium, Finland, Germany, Belgium and Ireland, as well as Denmark, France and the Netherlands, Luxembourg and Sweden. Within CC, Austria, Belgium, Ireland, Finland and Estonia are most similar, followed by Denmark, France, Luxembourg, Germany, the Netherlands and Sweden. In RL, Austria, Denmark, France, the Netherlands, Luxembourg and Sweden are most similar, as well as Estonia, Finland, Belgium and Ireland. In the EGDI, Denmark, Finland, Sweden, France, Germany and the Netherlands are most similar, followed by Estonia, Austria, Ireland and Luxembourg.

Cluster 2 comprises two countries (Bulgaria, Romania). This is a cluster characterized by the worst values in all indicators.

Cluster 3 comprises five countries (Croatia, Czech Republic, Hungary, Latvia, Slovakia). These are the countries that are the second worst in the EGDI. In GE, the Czech Republic and Latvia are most similar, followed by Croatia, Hungary and Slovakia. Croatia and Hungary and then Latvia and Slovakia are the most similar in CC. In RL, Hungary and Slovakia are most similar, followed by the Czech Republic and Latvia.

Cluster 4 comprises six countries (Cyprus, Lithuania, Malta, Portugal, Slovenia, Spain). These are the states that are ranked second in terms of values in GE, CC and RL. The greatest similarity in GE is between Cyprus, Malta and Spain and also between Lithuania and Slovenia. Cyprus, Spain and Malta and Lithuania are most similar in CC. Lithuania, Malta, Spain and Slovenia are most similar in RL. The greatest similarity in EGDI is between Cyprus, Slovenia and Lithuania and then Malta and Portugal.

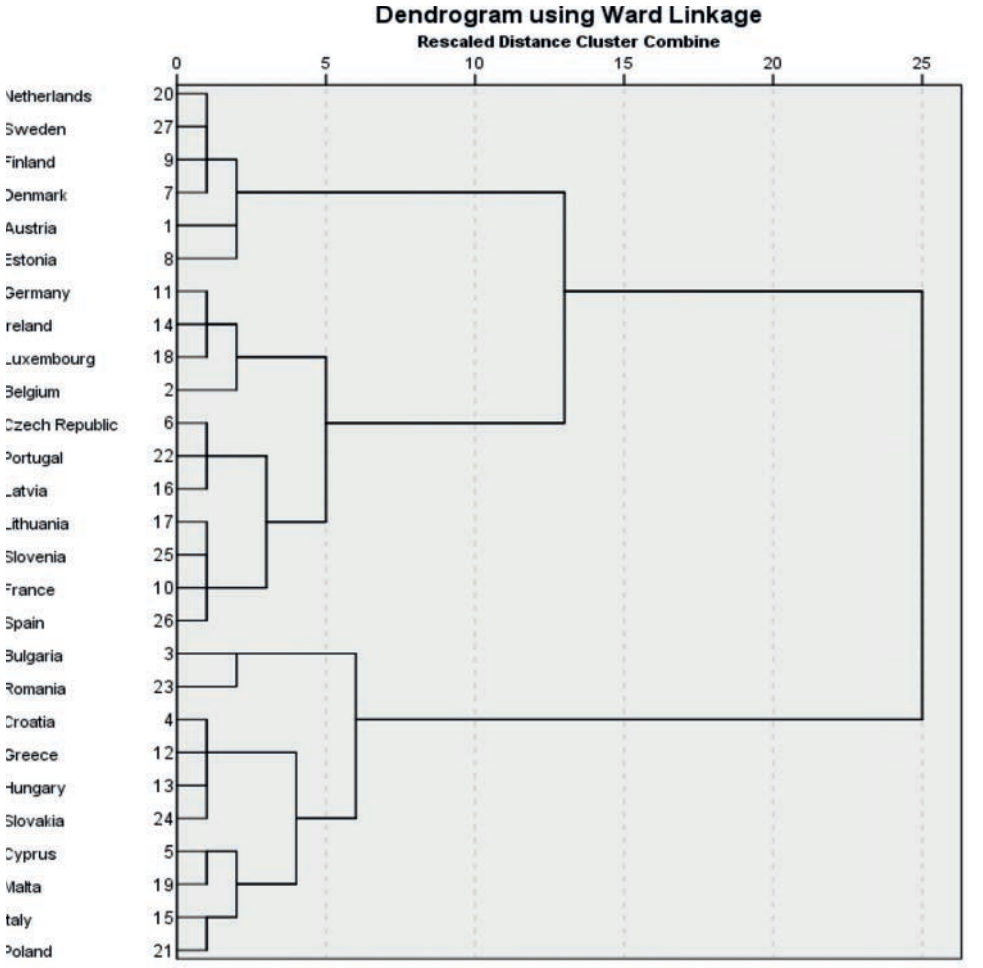
Cluster 5 comprises three countries (Greece, Italy, Poland). These are the second-ranked states within the EGDI, within which they are all similar. The greatest similarity in the remaining indicators is mainly between Greece and Italy.

Table 7: Average cluster values in 2018

Cluster	EGDI	GE	CC	RL
1. cluster	0.86	92.79	94.18	93.53
2. cluster	0.69	53.37	50	58.17
3. cluster	0.71	74.62	63.37	73.27
4. cluster	0.79	81.09	74.28	81.41
5. cluster	0.80	68.43	64.42	61.22

Source: own processing

Figure 8: Dendrogram of Similarities in EU Countries in 2020



Source: own processing

The dendrogram shows the possible division of states into 5 clusters.

Cluster 1 comprises six countries (Austria, Denmark, Estonia, Finland, Netherlands, Sweden). These are the states that achieve the highest values in all indicators. Denmark, Finland, the Netherlands and Sweden are most similar in GE, CC and EGDI. Austria, Denmark, Finland and Sweden are most similar in RL.

Cluster 2 comprises four countries (Belgium, Germany, Ireland, Luxembourg). This is the second-best cluster in the GE, CC and RL indicators, in which, including EGDI, the countries Germany, Ireland and Luxembourg are most similar.

Cluster 3 comprises two countries (Bulgaria, Romania). This is a cluster characterized by the worst values in all indicators.

Cluster 4 comprises eight countries (Croatia, Cyprus, Greece, Hungary, Italy, Malta, Poland, Slovakia). It is the second worst cluster in GE, CC and RL. Croatia, Greece, Italy, Poland and Slovakia are most similar in GE. Croatia, Greece, Hungary and then Cyprus, Italy, Malta and Slovakia are the most similar in CC. Croatia, Greece, Italy, Poland, followed by Cyprus, Poland and Hungary are most similar in RL. In the EGDI, Malta, Poland, Cyprus and Italy are most similar, followed by Croatia, Hungary and Slovakia.

Cluster 5 comprises seven countries (Czech Republic, France, Latvia, Lithuania, Portugal, Slovenia, Spain). It is the second-best cluster in EGDI. France, Slovenia and then the Czech Republic, Latvia, Lithuania, Portugal and Spain are most similar in GE. Spain, Slovenia, Portugal, Latvia are most similar in CC. In RL, the Czech Republic, Latvia, Lithuania, Slovenia and Spain are most similar. France and Lithuania, Spain and Slovenia, and the Czech Republic and Portugal are the most similar in EGDI.

Table 8: Average cluster values in 2020

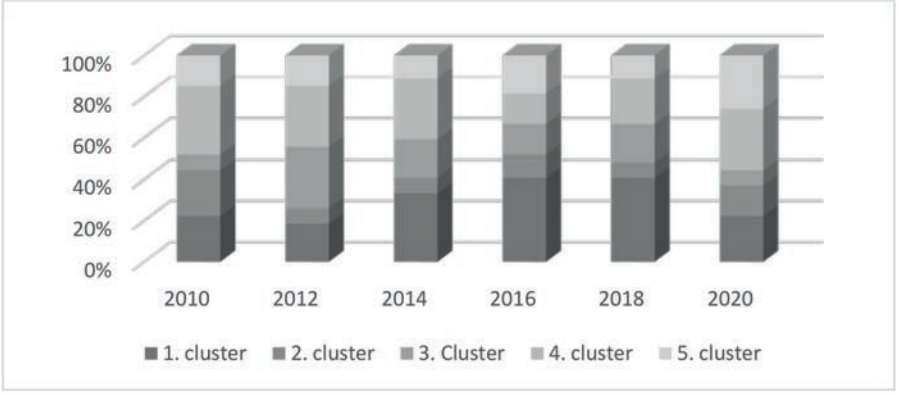
Cluster	EGDI	GE	CC	RL
1. cluster	0.94	95.6	96.15	95.99
2. cluster	0.83	90.14	93.27	91.47
3. cluster	0.78	43.51	49.28	57.45
4. cluster	0.82	70.91	64.84	67.43
5. cluster	0.84	81.46	77.54	82.97

Source: own processing

4 Discussion

Figure 9 shows the distribution of countries into individual clusters.

Figure 9: Distribution of countries by individual clusters between 2010–2020



Source: own processing

In 2010 a total of 5 clusters were created through cluster analysis. Cluster No. 1 includes countries that represent northern and central Europe. All countries except Sweden are members of the Eurozone. This cluster is characterized by the highest values of GE, CC and RL and the second highest level of EGDI. Cluster No. 2 includes countries that represent the North, the West and, in the case of Estonia, the East of Europe. This cluster is characterized by the highest level of EGDI and the second highest level of GE, CC and RL indicators. All countries are members of the Eurozone. Cluster 3 includes countries that are in the east of Europe, and it is a cluster that shows the worst values in all monitored indicators. Cluster 4 includes countries that represent central, southern and south-eastern Europe. According to the average values of all indicators, these are the countries that are the second worst. The last cluster 5 includes countries that represent the south and south-east of Europe. In terms of average values, this is a cluster that ranked 3rd.

In 2012, a total of 5 clusters were created through cluster analysis. Cluster No. 1 includes countries that represent central and western Europe. All countries are members of the Eurozone. This cluster is characterized by the second highest overall GE, CC and RL values. Cluster 2 includes countries that are in the east of Europe, and it is a cluster that shows the worst values in all monitored indicators. Cluster No. 3 includes countries that represent central, southern, eastern and south-eastern Europe. This cluster is characterized by the worst values after the previous one. Cluster 4 includes countries that represent them and the south-east of Europe. According to the average values of all indicators, these are the countries that are the third worst. The last cluster 5 includes countries that represent the north of Europe. In terms of average values, this is the best cluster.

In 2014, a total of 5 clusters were created through cluster analysis. Cluster No. 1 includes countries that represent northern, central and western Europe. All countries except Sweden are members of the Eurozone. This cluster is characterized by the highest values of GE, CC and RL and the second highest level of EGDI. Cluster 2 includes countries that are in the east of Europe, and it is a cluster that shows the worst values in all monitored indicators. Cluster #3 includes countries that represent South, Southeast and Central Europe. According to the average values of the GE, CC and RL indicators, these are the countries that are the second worst, and in the case of EGDI it is in 3rd place. All countries are members of the Eurozone. Cluster 4 includes countries that represent central, southern and south-eastern Europe. According to the average values of the GE, CC and RL indicators, these are the countries that are the third worst, and in the case of EGDI, it is even the penultimate place. The last cluster 5 includes countries that represent the south, south-east and north of Europe. In terms of mean values, it is the second-best cluster for GE, CC and RL and the best cluster for EGDI. All these countries are members of the Eurozone.

In 2016, a total of 5 clusters were created through cluster analysis. Cluster #1 includes countries that represent North, Central, West and South-East Europe. All countries except Sweden are members of the Eurozone. This cluster is characterized by the highest values of all indicators. Cluster 2 includes countries that are in the east and south of Europe and is the cluster that shows the worst values in all monitored indicators. Cluster #3 includes countries that represent South, Southeast and Central Europe. According to the average values of the GE, CC and RL indicators, these are the countries that are the second worst, and in the case of EGDI it is in 3rd place. All countries are members of the Eurozone.

Cluster 4 includes countries that represent central, southern and south-eastern Europe. According to the average values of the GE, CC and RL indicators, these are the countries that are the third worst, and in the case of EGDI, it is even the penultimate place. The last cluster 5 includes countries that represent the south and south-east of Europe. In terms of average values, it is the second-best cluster for all indicators. All these countries are members of the Eurozone. In 2016, compared to 2014, 8 states changed their cluster. These are Greece, Lithuania, Malta, Poland, Portugal, Slovenia, Estonia, Finland.

In 2018, a total of 5 clusters were created through cluster analysis. Cluster #1 includes countries that represent North, Central, West and South-East Europe. All countries except Sweden are members of the Eurozone. This cluster is characterized by the highest values of all indicators. Cluster 2 includes countries that are in the East and is the cluster that shows the worst values in all monitored indicators. Cluster #3 includes countries that represent South, Southeast and Central Europe. According to the average values of the GE, CC and RL indicators, these are the countries that are the third worst and in the case of the EGDI it is the 4th place. Cluster 4 includes countries that represent them and the south-east of Europe. According to the average values of the GE, CC and RL indicators, these are the countries that are the second best, and in the case of EGDI it is a close third place. The last cluster 5 includes countries that represent southern and central Europe. In terms of average values, it is the second best cluster in the case of EGDI and the 4th worst in the case of other indicators. All these countries are members of the Eurozone. In 2018, compared to 2016, 11 states changed their cluster. These are the Czech Republic, Latvia, Slovakia, Lithuania, Malta, Portugal, Slovenia, Spain, Greece, Italy, Poland.

In 2020, a total of 5 clusters were created through cluster analysis. Cluster #1 includes countries that represent North, Central, West and South-East Europe. All countries except Sweden are members of the Eurozone. This cluster is characterized by the highest values of all indicators. Cluster No. 2 includes countries that primarily represent western Europe. According to the average values of the GE, CC and RL indicators, these are the countries that are the second best and in the case of EGDI it is the 3rd place. Cluster 3 includes countries that are in the East and this is the cluster that shows the worst values in all monitored indicators. Cluster 4 includes countries that represent them and south-east and central Europe. According to the average values of the indicators of all indicators, this is the cluster that is the penultimate. The last cluster 5 includes countries that represent central, western and eastern Europe. In terms of average values, it is the second-best cluster in the case of EGDI and the 3rd best in the case of other indicators. In 2018, compared to 2016, 17 states changed their cluster. These are Belgium, Germany, Ireland, Luxembourg, Croatia, Greece, Hungary, Italy, Poland, Slovakia, Czech Republic, France, Latvia, Lithuania, Portugal, Slovenia, Spain.

Cluster No. 1 is relatively homogeneous in the analysed years and mostly consists of Eurozone countries and states in the west and north of Europe, which corresponds to, for example, Yerina, Demydiuk & Demydiuk (2021) or Androniceanu & Georgescu (2023). The EU member states in Central and Eastern Europe did not show any significant progress in the development of e-government during the evaluated years. Occasional exceptions in different years were the Czech Republic, Poland, Lithuania and Slovenia. it can be stated that the cluster with high EGDI value is also the cluster with the highest average values of GE, CC and RL. Furthermore, it can be stated that Romania and Bulgaria

in all monitored years were always the worst in terms of the analysed indicators. Similar results were found in Andronicean & Georgescu (2023) and Pakhnenko & Kuan (2023).

It is worth noting that individual states did not differ much in their levels in uniform years. In the same clusters, there were mostly states that have something in common (for example, from a geographical point of view or history). Another finding is that, in comparison between 2010 and 2020. there was an increase in the GE indicator in most countries, especially in Belgium, Bulgaria, Cyprus, Poland, Romania, and Slovakia. Within the CC indicator, there was a slight increase in this indicator, especially in Bulgaria, Cyprus, France, Hungary, Malta and Spain, but at the same time there was also a significant decrease in some countries such as Estonia, Latvia and Lithuania. There was also a slight increase in the RI indicator, namely in countries such as Cyprus, Greece, Malta and Spain, on the contrary, there was a decrease in Latvia, Lithuania, Romania and Slovakia. Significant changes in these indicators occurred mainly in clusters characterized by worse values.

5 Conclusion

E-government represents a revolutionary area that should be given a lot of attention at the moment. This trend is accompanied by an increase in the number of initiatives that lead to the improvement of public service delivery as well as to the improvement of interaction between citizens and therefore businesses and the government. Over the past 10 years, significant changes have taken place in the EU member states in the area of digitization of public administration.

Based on data from 27 EU countries, the article analysed the relationship between the digitization of countries (based on the E-Government Development Index) and the quality of public administration (based on Government effectiveness, Control of corruption and Rule of Law). It was found that the digitization of EU countries through the EGDI indicator increases over time for all countries, however significant differences can be found between countries. In 2020. all states belong to the group of countries with a very high EGDI, which is 24 more countries than in 2010. Through correlation analysis, it was found that there is a statistically significant positive correlation between government digitization and public administration performance. Through cluster analysis, 5 clusters were created in individual years. Countries such as Finland, Sweden, Denmark, the Netherlands, and Luxembourg appeared in the leading clusters. On the contrary, Bulgaria and Romania were in the worst clusters. Membership in the best and worst clusters does not change much in the monitored years. The results also indicate that countries with a high level of the EGDI indicator also show a high level of the other indicators and vice versa. The results of this research can help economic policy makers to monitor, evaluate their development and compare it with other countries.

The article allows countries with a similar level to be singled out. The limit of this research is that the methodology used for selected indicators, for example EGDI, does not capture all dimensions of digitalization of public administration. Future research could increase the sample set by adding additional countries or could analyse individual countries, especially those that changed from one servant to another within the monitored years.

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