# “Adult education demand and competitiveness patterns across European countries”


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# ADULT EDUCATION DEMAND AND COMPETITIVENESS PATTERNS ACROSS EUROPEAN COUNTRIES

## Abstract

The study aims to empirically group European countries based on competitiveness determinants and adult education demand to form a generalized cluster representation of their socio-economic characteristics. The sample covers 36 European countries from 2015 to 2024. The information base was formed using a set of indicators derived from the Global Competitiveness Index (GCI), together with an indicator reflecting adult education demand. The methodology includes standardization of indicators, selection of relevant variables using principal component analysis, and cluster analysis. The first two principal components explain 76.3% of the total variance, allowing a substantial reduction in the dimensionality of the dataset while preserving most of the information contained in the initial indicators. Clustering was conducted using Ward's hierarchical method and the k-means algorithm, with verification of differences between clusters by analysis of variance ($p < 0.05$). To examine structural changes over time, clustering was performed for three benchmark years: 2015, 2020, and 2024. The results reveal five clusters of countries differing in institutional development, innovation potential, business environment characteristics, and adult education participation. A relatively stable core of highly competitive economies was identified, including Austria, Belgium, Germany, France, Ireland, Luxembourg, Denmark, the Netherlands, Norway, Sweden, Finland, and Switzerland. Other clusters show greater variability in composition. Across the benchmark years selected within the 2015–2024 observation period, Ukraine remained within the cluster characterized by the lowest values of competitiveness determinants and adult education demand, reflecting persistent structural constraints in the development of human capital and lifelong learning systems.

**Keywords** lifelong learning, human capital, economic competitiveness, institutional development, innovation capacity, labor skills, Europe

**JEL Classification** I25, O15, O47

## INTRODUCTION

Adult education is a component of socio-economic development that reflects the ability of countries to ensure the continuous updating of knowledge and skills of the population after the completion of formal education. In European countries, the level of adult participation in learning varies significantly, reflecting different approaches to the organization of adult education systems and their different roles in the structure of national development priorities. These differences are shaped by institutional conditions, the state of the labor market, the level of economic development, and educational policies.

At the same time, European countries show significant differentiation in terms of competitiveness, which is determined by a combination of institutional, economic, innovative, and social factors. Competitiveness in this context is a generalized characteristic of the economy's ability to ensure sustainable growth, efficient use of resources, and adaptation to change. Adult education is potentially



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linked to these processes as it affects the quality of the workforce, opportunities for professional mobility, and the economy's ability to respond to structural changes.

Nevertheless, the relationship between countries' competitiveness and demand for adult education is not clear-cut. Adult education can serve different purposes in different countries: it can be a factor supporting an already high level of economic development or a tool for compensating for limitations associated with lower competitiveness. The lack of a generalized understanding of how these characteristics combine within the European space complicates the comparative assessment of countries. It prevents the identification of typical models of their development.

Under these conditions, there is a need for a systematic comparison of European countries in terms of competitiveness and demand for adult education, as well as the identification of stable patterns in their combination in dynamics.

## 1. LITERATURE REVIEW

Over the past two decades, adult education and lifelong learning have transformed from a peripheral area of educational policy into a key element of socio-economic development and national competitiveness. In today's knowledge economy, continuous updating of skills and competencies is seen not only as an individual strategy for adapting to changes in the labor market, but also as an institutionally driven mechanism for supporting innovation, productivity, and economic sustainability (Green, 2006; Ogawa, 2009; Kuzior et al., 2024; Ng, 2013; Barros, 2025; Chiang et al., 2024; Hrmo et al., 2015).

Research in adult education emphasizes that the adult population is the primary carrier and transmitter of human capital amid demographic aging, digital transformation, and structural shifts in employment (Jarvis, 2007; Boeren et al., 2010; Charungkaittikul & Henschke, 2014). In this context, adult participation in formal and informal education is increasingly analyzed as a macroeconomic factor that mediates the link between the education system and long-term economic growth (Desjardins et al., 2006; Rubenson & Desjardins, 2009). These issues are particularly relevant in the European context, where lifelong learning is institutionally enshrined as one of the main strategic goals for the development of human capital and competitiveness of EU member states (Holford et al., 2014).

A significant part of scientific research devoted to institutional and political determinants of adult education development in Europe focuses on the role of the institutional environment in shaping demand for adult education. Institutional quality, in particular the effectiveness of public administration, the stability of the legal framework, and the coherence of policies in the fields of education, the labor market, and social protection, determines the opportunities and incentives for the adult population to participate in learning (Saar et al., 2013; Kalenda & Desjardins, 2025).

Holford et al. (2014) considered adult education a separate supranational political space within which a common regulatory framework is formed, but significant cross-country differences remain. Similarly, Mikulec (2018) emphasizes that European countries demonstrate different models of integrating adult education into national competitiveness systems, which is due to historical, economic, and social characteristics.

Empirical studies show that more developed institutional systems contribute not only to higher levels of adult participation in learning but also to a more effective conversion of educational investments into economic outcomes (Gaimard & Kroll, 2014; Rubenson & Desjardins, 2009).

In addition, in contemporary scientific discourse, competitiveness is increasingly viewed through the prism of the quality and structure of human capital. The level of skills development is a key factor in productivity, innovation capacity, and countries' positions in global competitiveness rankings (Appleby & Bathmaker, 2006; Mayo, 2009).

In this context, adult education plays a compensatory role, reducing structural imbalances in the

labor market and increasing workforce adaptability (Oganisjana & Koke, 2012; Mamaqi et al., 2011). Németh (2010) shows that countries that institutionally support lifelong skills development form more sustainable models of economic development.

In addition, the development of skills in adulthood is closely linked to the capacity of economies to innovate. Empirical results show that investment in adult education correlates positively with indicators of innovation activity and technological readiness (Dima et al., 2018; Zhang et al., 2022).

Cross-country studies reveal typical combinations of educational, institutional, and economic characteristics that determine countries' competitiveness. In particular, Bulut et al. (2022) and Denkowska et al. (2020) argue that EU countries differ significantly in the nature of the relationship between adult education, GDP, and innovation indicators. High rates of adult participation in learning do not always automatically translate into increased competitiveness if they are not supported by the appropriate institutional and business infrastructure (Guimarães & Antunes, 2014; Herdon et al., 2015). This highlights the need for a comprehensive approach to combine educational, economic, and institutional variables.

Most studies use composite indices, econometric models, or individual indicators to assess the role of adult education in ensuring competitiveness (Green, 2006; Dima et al., 2018). At the same time, such approaches often fail to reveal the internal heterogeneity of country groups and typical combinations of factors. In this context, multidimensional analysis methods, in particular cluster analysis and principal component analysis, are becoming increasingly popular, as they allow for the identification of latent structures and the formation of generalized country typologies (Bulut et al., 2022; Denkowska et al., 2020). However, most existing studies either focus on a limited number of indicators or do not take into account the dynamic nature of changes in the structure of adult education and competitiveness.

Kuzior et al. (2023) substantiate the role of lifelong learning as an important factor in the development of innovative potential within the framework of sustainable development. Their study confirms that adult learning should be considered not only as a social or educational phenomenon, but also as a factor associated with broader socio-economic transformations and innovation-oriented development. At the same time, Onopriienko (2023) proposed a methodological approach to clustering European countries according to the most relevant determinants of competitiveness and adult education demand. Using data for 2012–2021, the study identified five clusters based on institutional quality, skills, business development, innovation potential, and participation in adult learning, and demonstrated both the relative stability of highly developed countries and the variability of cluster composition among less competitive economies.

However, the existing studies do not eliminate the need for further research. In particular, Kuzior et al. (2023) focus primarily on the conceptual and empirical relationship between lifelong learning and innovative potential. In contrast, the internal heterogeneity of European countries and the dynamics of their grouping remain outside the central scope of the analysis. At the same time, although Onopriienko (2023) developed a cluster-based approach to the comparative analysis of European countries, the extension of the observation period to more recent years is essential, since the socio-economic context after 2021 was shaped by new large-scale shocks, including the consequences of the COVID-19 pandemic, post-pandemic restructuring, and the full-scale war in Ukraine. Therefore, there is a need not simply to reproduce the existing clustering logic, but to update and deepen it under new conditions in order to identify whether the previously observed country groupings remain stable and how the role of adult education demand has evolved in the contemporary European context.

Overall, despite the significant number of studies analyzing adult education, skills development, and country competitiveness, most of them focus on individual aspects of these processes. In particular, adult education is usually considered in the context of the adult population's participation in learning, the characteristics of educational programs, or the features of educational policy. At the same time, the competitiveness of countries is analyzed mainly through macroeconomic, in-


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stitutional, or innovation indicators. This division of research focus is justified, given the complexity of each area. However, it limits the possibility of a holistic view of how the demand for adult education correlates with various characteristics of competitiveness at the level of national economies. In this regard, there is a growing need to generalize empirical results in such a way that they allow countries to be compared not only by individual indicators, but also by the nature of the combination of educational, institutional, and economic characteristics that shape their positions in the European space.

The purpose of the study is to develop a cluster distribution of European countries according to competitiveness characteristics and demand for adult education. This enables comparison across countries, identification of typical combinations of relevant indicators, and use of the resulting clusters as a generalized empirical tool for further comparative research and the development of scientific approaches to analyzing competitiveness in the European context.

## 2. METHODS

The methodological basis of the study is a multidimensional quantitative approach that clusters European countries according to the most relevant determinants of national economic competitiveness and demand for adult education. The analytical logic of the study involves a sequential combination of data reduction methods and multidimensional clustering methods to identify stable cross-country structures.

### 2.1. Data and sample

The empirical sample comprises 36 European countries, and the study's time horizon spans 2015–2024 (Appendix A). The dataset, therefore, represents a balanced panel of cross-country observations, allowing the analysis of both cross-sectional differences and temporal dynamics in competitiveness and adult education participation.

The information base was formed for 2015–2024, which made it possible to identify general relationships between indicators and ensure the robustness of the analytical framework.

To examine structural changes over time while maintaining analytical clarity, cluster analysis was conducted for three benchmark years (2015, 2020, and 2024) representing the beginning, mid-point, and final stage of the observation period. This benchmark-based approach enables the identification of persistent shifts in country groupings while reducing sensitivity to short-term fluctuations.

The choice of 2015, 2020, and 2024 as benchmark years is justified both methodologically and substantively. Methodologically, these years represent evenly distributed points within the study period and therefore provide a clear basis for tracing medium-term changes in the structure of country groupings. Substantively, each of these years corresponds to a distinct socio-economic context: 2015 reflects the initial stage of the observation period, 2020 captures the structural disruption associated with the COVID-19 pandemic, and 2024 reflects the most recent configuration shaped by post-pandemic adaptation and geopolitical shocks, including the consequences of the full-scale war in Ukraine.

The information base of the study was formed using a set of indicators derived from the Global Competitiveness Index (GCI), which reflect its key dimensions, including institutions, skills, business development, and innovation capacity. These indicators were used as separate variables in the analysis rather than as an aggregate index. Along with these indicators, an independent indicator of adult education demand (ae_demand) was included, characterizing the share of the population aged 18–64 participating in education.

The set of indicators used in the analysis includes:

- institutions (*inst*);
- infrastructure (*infr*);
- use of information and communication technologies (*ict*);
- macroeconomic stability (*macr*);
- health (*health*);
- skills;
- efficiency of product markets (*pr_mark*);
- labor market efficiency (*lab_mark*);
- financial system development (fin_syst);
- market size (*m_size*);
- business development (*busin*);
- innovation potential (*innov*).

In this study, indicators are the initial variables used in the analysis, while components are the latent variables obtained through principal component analysis. To account for the structural heterogeneity of national economies, countries were additionally classified according to GDP per capita using a threshold value of 40 thousand US dollars. All calculations were performed using STATISTICA 12 software.

The research methodology is implemented within a sequential multi-stage framework that ensures logical consistency between analytical steps and improves the reliability of cross-country comparisons.

Stage 1 is data preparation and standardization. All indicators included in the study were standardized to eliminate the influence of different measurement scales and ensure comparability between countries. At this stage, a consistent observation matrix was formed, which served as the basis for subsequent multidimensional analysis.

Stage 2 is dimensionality reduction using principal component analysis. Given the potential correlations between indicators and the multidimensionality of the dataset, the principal component method was applied. This procedure allows for reducing the dimensionality of the initial set of variables while preserving the essential information contained in the dataset and avoiding redundancy of indicators in subsequent clustering. At this stage, each principal component is interpreted as a linear combination of the standardized indicators, formalized by the corresponding principal component equation:

$$s_i = \sum_{1}^{m} b_{ij} Comp_j, \quad (1)$$

where $s_i$ – standardized value of the *i*-th indicator with unit variance; $m$ – the total number of indicators participating in the study; $b_{ij}$ – the value of the factor load of the *j-th* component on the *i-th* indicator.

The significance of each component is assessed by the sum of the squares of the factor loadings, which reflects the proportion of explained variance:

$$\lambda_j = \sum_{1}^{m} b^2_{ij}. \quad (2)$$

The optimal number of components was determined using Kaiser's criterion, cumulative variance analysis, and the scree plot. To improve interpretability, orthogonal Varimax rotation was applied. As a result, the most relevant indicators were identified on the basis of the factor loadings of the first two components and used as the input basis for the cluster analysis.

Principal component analysis was applied to the full observation period in order to identify the most relevant indicators for the study as a whole and to reduce dimensionality on the basis of the complete data array. The subsequent cluster analysis was then carried out only for the selected benchmark years, allowing comparison of country configurations at key temporal points without overloading the study with 10 separate annual clustering solutions.

Stage 3 is hierarchical clustering. Countries were grouped according to the similarity of their socio-economic characteristics. At the first step, a hierarchical clustering procedure was applied in order to determine the optimal number of clusters based on inter-object distances. The agglomerative procedure is based on the principle of minimizing the distance between clusters:

$$D = \min\left(dist\left(x_{11}, x_{m1}\right)\right) \quad (3)$$

while the divisional approach follows the inverse principle of maximizing distances:

$$D = \max\left(dist\left(x_{11}, x_{m1}\right)\right) \quad (4)$$

The Ward method was used to construct the hierarchical cluster structure.

Stage 4 is k-means clustering. At the next stage, the cluster configuration was refined using the non-hierarchical k-means method, which iteratively updates cluster centers and redistributes observations until the solution stabilizes.

Stage 5 is validation of clustering results. The robustness of the obtained cluster structure was as-


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sessed using analysis of variance (ANOVA), which allows testing the statistical significance of differences between clusters for each of the indicators included in the model.

## 3. RESULTS

Within the framework of the proposed methodological approach, the obtained results reflect the structure of interrelationships between the determinants of competitiveness and the demand for adult education, as well as the cluster differentiation of European countries in a dynamic perspective.

First, the principal component method was applied to determine the contribution of individual indicators to the overall variation of the multidimensional dataset and to identify the most relevant determinants of competitiveness and adult education demand.

The results of the eigenvalue decomposition of the correlation matrix made it possible to assess the explanatory capacity of each principal component. The obtained eigenvalues and the corresponding proportions of explained variance are presented in Table 1. In this context, principal components are interpreted as latent variables derived from the initial set of indicators through dimensionality reduction.

**Table 1.** Principal component method for selecting the most relevant determinants of a country's competitiveness

| Components | Value | Dispersion | Cumulative dispersion |
|---|---|---|---|
| Component 1 | 8.6 | 66.2 | 66.2 |
| Component 2 | 1.3 | 10.1 | 76.3 |
| Component 3 | 0.7 | 5.4 | 81.7 |
| Component 4 | 0.6 | 4.3 | 86.0 |
| Component 5 | 0.5 | 3.6 | 89.6 |
| Component 6 | 0.4 | 2.8 | 92.4 |
| Component 7 | 0.3 | 2.0 | 94.4 |
| Component 8 | 0.2 | 1.6 | 96.0 |
| Component 9 | 0.2 | 1.4 | 97.4 |
| Component 10 | 0.2 | 1.1 | 98.5 |
| Component 11 | 0.1 | 0.8 | 99.3 |
| Component 12 | 0.1 | 0.5 | 99.8 |
| Component 13 | 0.0 | 0.2 | 100.0 |

The cumulative variance explained by the first two components reaches 76.3%, which exceeds the commonly accepted threshold of 70% for multidimensional statistical analysis. This result confirms that the majority of the variability of the initial indicators can be adequately represented using only two latent components, making it possible to significantly reduce the dimensionality of the dataset without substantial information loss.

The dominance of the first principal component indicates a generalized dimension of competitiveness, integrating institutional development, skill formation, business sophistication, innovation potential, and adult learning participation. The second component captures additional variation associated primarily with differences in market scale and structural characteristics of national economies. Thus, the obtained results confirm the feasibility of using the first two components as a reduced analytical basis for the subsequent cluster analysis of European countries.

Additional confirmation of the optimal number of components was obtained based on the scree plot presented in Figure 1, which illustrates the distribution of eigenvalues across principal components. The scree plot demonstrates a clear inflection point after the second component, indicating that further components contribute only marginally to the explanation of total variance. This observation is consistent with the eigenvalue analysis presented in Table 1 and confirms the appropriateness of retaining the first two components for further analysis.

Second, the factor loadings of the indicators within the first two components were examined (Table 2).

**Table 2.** Factor loadings of indicators in the first and second components

| Indicator | Component 1 | Component 2 |
|---|---|---|
| Inst | −0.92 | −0.10 |
| Infr | −0.79 | 0.31 |
| Ict | −0.74 | −0.39 |
| Macr | −0.70 | −0.26 |
| Health | −0.67 | 0.27 |
| Skills | −0.89 | −0.18 |
| p_rmark | −0.72 | 0.16 |
| lab_mark | −0.78 | −0.41 |
| fin_syst | −0.73 | 0.12 |
| m_size | −0.35 | 0.71 |
| Busin | −0.90 | 0.13 |
| Innov | −0.94 | 0.19 |
| ae_demand | −0.90 | −0.09 |

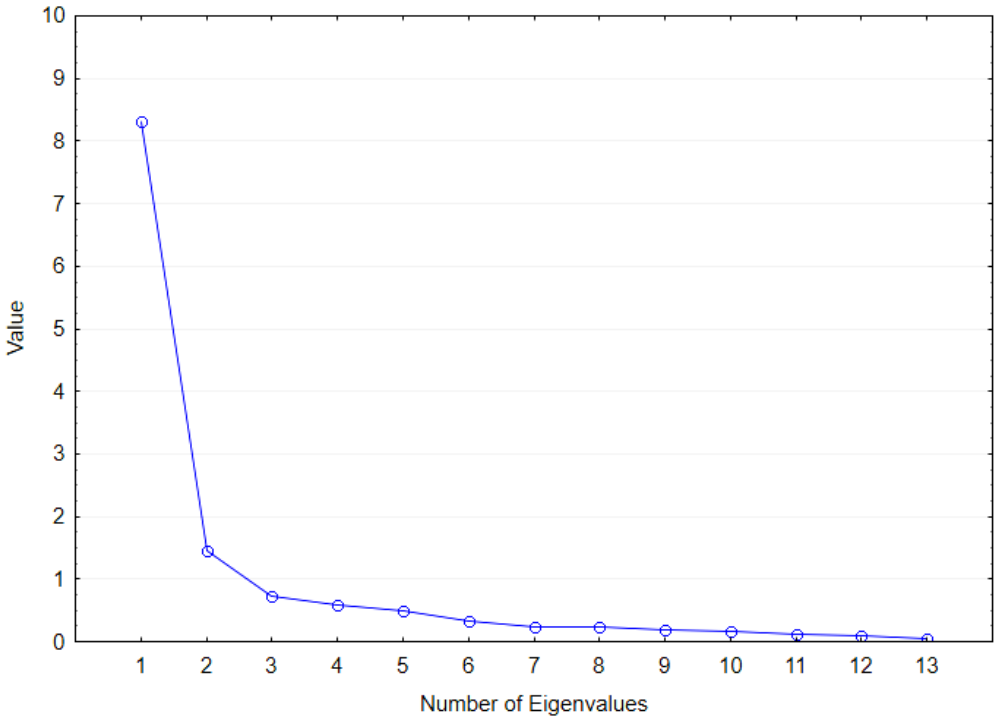


**Figure 1.** Scree plot of principal components

The highest factor loadings in absolute terms within the first component are observed for the institutions (inst), skills (skills), business development (busin), innovation potential (innov), and demand for adult education (ae_demand). This pattern suggests that the first principal component reflects a generalized institutional–innovation dimension of competitiveness, integrating both structural economic characteristics and the capacity of national systems to support lifelong learning. These five indicators were therefore selected as the core variables for the subsequent cluster analysis.

Third, European countries were grouped according to the selected indicators reflecting institutional quality, skills development, business sophistication, innovation potential, and demand for adult education. Clustering was implemented using a two-stage procedure. First, hierarchical clustering based on Ward's method with Euclidean distance was applied to determine the optimal number of clusters. The analysis indicated the presence of five relatively homogeneous groups of countries. Next, the k-means clustering algorithm was applied to refine the cluster configuration and determine the final allocation of countries across clusters by minimizing within-cluster variance. The resulting cluster composition for 2015 is presented in Table 3.

**Table 3.** Cluster composition of European countries according to competitiveness determinants and demand for adult education, 2015

| Cluster | Countries |
|---|---|
| Cluster 1 | Austria, Belgium, Ireland, Luxembourg, Germany, France |
| Cluster 2 | Estonia, Cyprus, Latvia, Malta, Iceland, Montenegro |
| Cluster 3 | Spain, Italy, Lithuania, Portugal, Slovenia, the Czech Republic, Poland |
| Cluster 4 | Denmark, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom, Finland |
| Cluster 5 | Bulgaria, Greece, North Macedonia, Romania, Serbia, Slovakia, Hungary, Ukraine, Croatia, Turkey |

The empirical sample includes 36 European countries, distributed across five clusters of different sizes. The identified grouping reflects meaningful cross-country differences in the combination of competitiveness determinants and adult education demand. The statistical significance of the clustering solution was verified using analysis of variance (ANOVA). The results are presented in Table 4, where all clustering indicators demonstrate statistically significant differences between clusters ($p < 0.05$).


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**Table 4.** Qualitative assessment of K-means clustering in 2015

| Indicator | Sum of squares between clusters | df | Sum of squares within clusters | df | F-test | p-level |
|---|---|---|---|---|---|---|
| Inst | 4810.52 | 4 | 561.84 | 31 | 66.40 | 0.000 |
| Skills | 1692.44 | 4 | 502.91 | 31 | 26.10 | 0.000 |
| Busin | 3056.77 | 4 | 398.26 | 31 | 59.50 | 0.000 |
| Innov | 5074.93 | 4 | 471.08 | 31 | 83.50 | 0.000 |
| ae_demand | 1815.63 | 4 | 612.37 | 31 | 23.00 | 0.000 |

The ANOVA results confirm that the selected indicators significantly differentiate the identified clusters. The highest F-statistics are observed for innovation potential and institutional quality, indicating their particularly strong role in shaping differences between country groups. The average values of the clustering indicators for 2015 are presented in Figure 2.

The analysis of cluster averages reveals clear structural differences among the identified groups. Cluster 4 includes highly developed Northern and Western European economies characterized by strong institutional systems, advanced innovation capacity, and the highest levels of participation in adult education. These countries demonstrate mature lifelong learning systems and a strong connection between education, innovation, and labor market adaptability.

Cluster 1 also consists of economically advanced countries with high GDP per capita and strong institutional environments. However, compared to Cluster 4, their average values of innovation performance and adult learning participation are slightly lower. Cluster 2 combines relatively small and open economies with comparatively strong human capital characteristics but more moderate overall competitiveness and innovation capacity. Cluster 3 includes countries with intermediate competitiveness profiles and moderate-to-growing levels of participation in adult education. These economies occupy a transitional position between the more advanced and lower-performing groups. Finally, Cluster 5, which includes Ukraine, is characterized by the lowest values across most competitiveness determinants and adult education indicators. Countries in this group typically demonstrate weaker institutional environments, lower

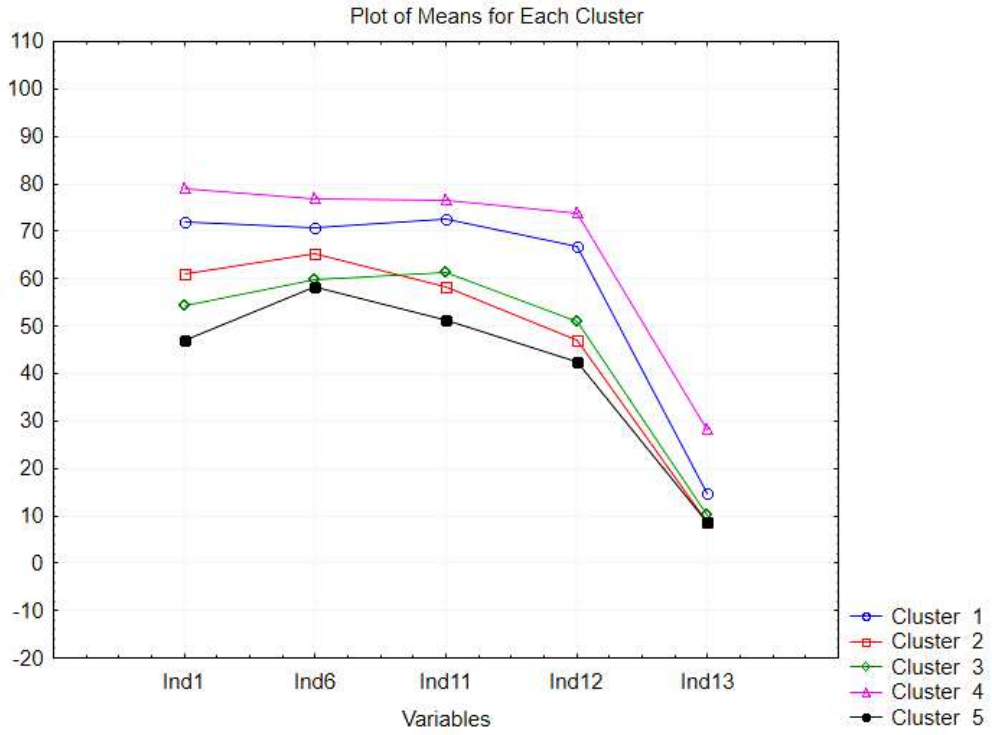


**Figure 2.** Average cluster values for the selected indicators in 2015

innovation potential, and more limited participation in lifelong learning systems.

A similar clustering procedure was conducted for 2020, which made it possible to identify structural shifts in the relationship between competitiveness determinants and demand for adult education across European countries.

First, hierarchical clustering based on Ward's method with Euclidean distance was used to determine the optimal number of clusters. The analysis again indicated the presence of five relatively homogeneous groups of countries. Second, the k-means algorithm was applied to refine the cluster configuration and assign countries to the final groups by minimizing within-cluster variance. The resulting cluster composition for 2020 is presented in Table 5.

**Table 5.** Cluster composition of European countries according to competitiveness determinants and demand for adult education in 2020

| Cluster | Countries |
|---|---|
| Cluster 1 | Estonia, Italy, Cyprus, Malta, Slovenia |
| Cluster 2 | Austria, Belgium, Germany, France, Ireland, Luxembourg |
| Cluster 3 | Spain, Portugal, the Czech Republic, Latvia, Lithuania, Poland, Croatia |
| Cluster 4 | Bulgaria, Greece, North Macedonia, Romania, Serbia, Slovakia, Hungary, Ukraine, Montenegro, Turkey |
| Cluster 5 | Denmark, Finland, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom, Iceland |

The statistical significance of the clustering solution was verified using analysis of variance (ANOVA). The results are presented in Table 6.

**Table 6.** Qualitative assessment of clustering performed using the k-means method in 2020

| Indicator | Between SS | Df | Within SS | df | F-test | p |
|---|---|---|---|---|---|---|
| Inst | 3920.41 | 4 | 497.52 | 31 | 66.11 | 0.000 |
| Skills | 1587.33 | 4 | 468.72 | 31 | 29.48 | 0.000 |
| Busin | 2106.27 | 4 | 349.91 | 31 | 52.27 | 0.000 |
| Innov | 6732.55 | 4 | 846.72 | 31 | 66.97 | 0.000 |
| ae_demand | 1598.24 | 4 | 728.14 | 31 | 18.21 | 0.000 |

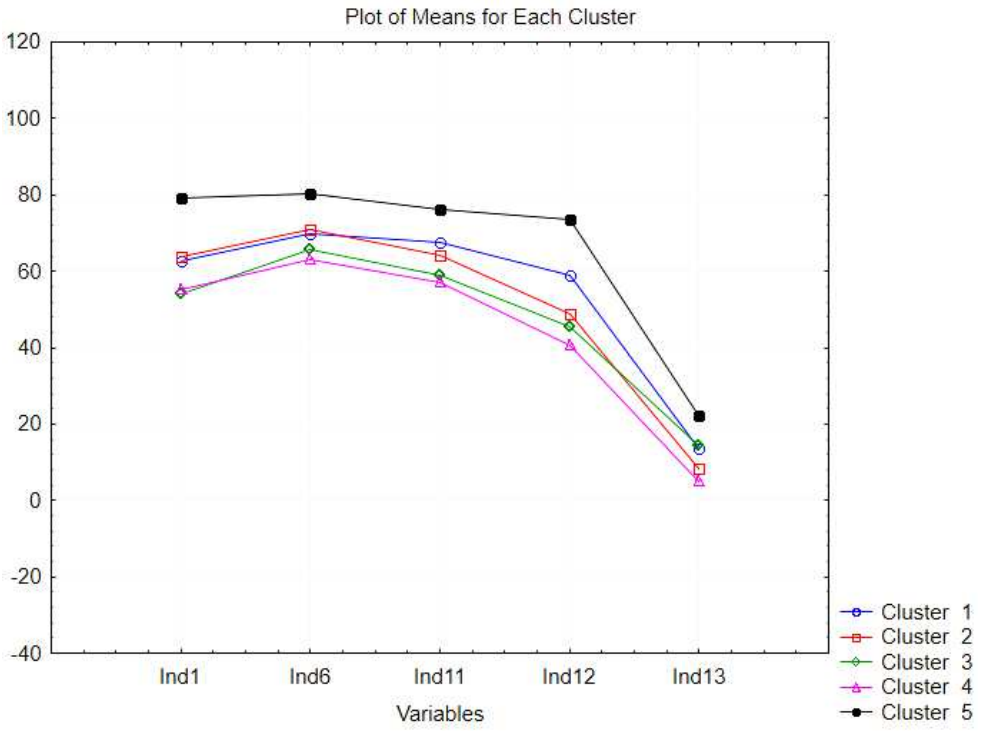


**Figure 3.** Average values of clusters in 2020


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According to the results presented in Table 5, all indicators used for clustering are statistically significant ($p < 0.05$). This confirms that the identified groups differ meaningfully in terms of institutional quality, skills, business sophistication, innovation potential, and adult education participation. The average values of clustering indicators for 2020 are presented in Figure 3.

The analysis of cluster averages indicates that the fifth cluster combines economically advanced Northern and Western European countries characterized by the highest average values of most indicators, including institutional quality, innovation capacity, and participation in adult education. These countries were better positioned to adapt to the pandemic shock due to stronger digital infrastructure, more resilient labor market institutions, and broader access to flexible learning formats.

The second cluster also includes highly developed economies with high GDP per capita and strong institutional and human capital characteristics. However, compared with the fifth cluster, their average innovation and adult learning indicators are somewhat lower, which suggests a more moderate pace of adaptation in the field of lifelong learning.

The first cluster consists of a relatively small group of countries with mixed structural characteristics. Although their institutional indicators are below those of the second cluster, they demonstrate comparatively stronger positions in several innovation-related dimensions and maintain moderate participation in adult education.

The third cluster groups countries with intermediate competitiveness profiles. These economies combine moderate institutional and business conditions with lower overall performance than the leading groups, although in some dimensions they remain close to the first cluster.

Finally, the fourth cluster, which includes Ukraine, is characterized by the lowest average values across most indicators. Countries in this group demonstrate weaker institutional environments, lower innovation capacity, and more limited participation in adult education. In 2020, this pattern reflects both pre-existing structural constraints and the unequal capacity of national systems to respond to the educational and labor market disruptions caused by COVID-19. Thus, the cluster configuration for 2020 captures not only cross-country differences in competitiveness but also the differentiated ability of European countries to absorb the shock of accelerated digital transformation in adult learning.

To assess the most recent configuration of the relationship between competitiveness determinants and adult education demand, the clustering procedure was repeated for 2024 using the same methodological framework. The results again indicate the formation of five clusters, reflecting persistent structural differences among European countries in institutional development, innovation performance, skills formation, and participation in lifelong learning. The final cluster allocation for 2024 is presented in Table 7.

**Table 7.** Cluster composition of European countries according to competitiveness determinants and demand for adult education in 2024

| Cluster | Countries |
|---|---|
| Cluster 1 | Estonia, Spain, Italy, Poland, Portugal, Slovenia, the Czech Republic |
| Cluster 2 | Bulgaria, Greece, North Macedonia, Romania, Serbia, Turkey, Ukraine, Montenegro |
| Cluster 3 | Cyprus, Latvia, Lithuania, Malta, Croatia, Slovakia, Hungary |
| Cluster 4 | France, Ireland, Iceland, Luxembourg, the United Kingdom |
| Cluster 5 | Austria, Belgium, Denmark, Finland, Germany, the Netherlands, Norway, Sweden, and Switzerland |

The correctness of the clustering solution was verified using analysis of variance, the results of which are presented in Table 8.

All clustering indicators remain statistically significant at $p < 0.05$, confirming the robustness of the identified cluster structure. The average values of clustering indicators for 2024 are presented in Figure 4.

The analysis of cluster averages reveals a clearer polarization of European countries by 2024. The fifth cluster includes the most competitive European economies and demonstrates the highest average values of most indicators. These coun-

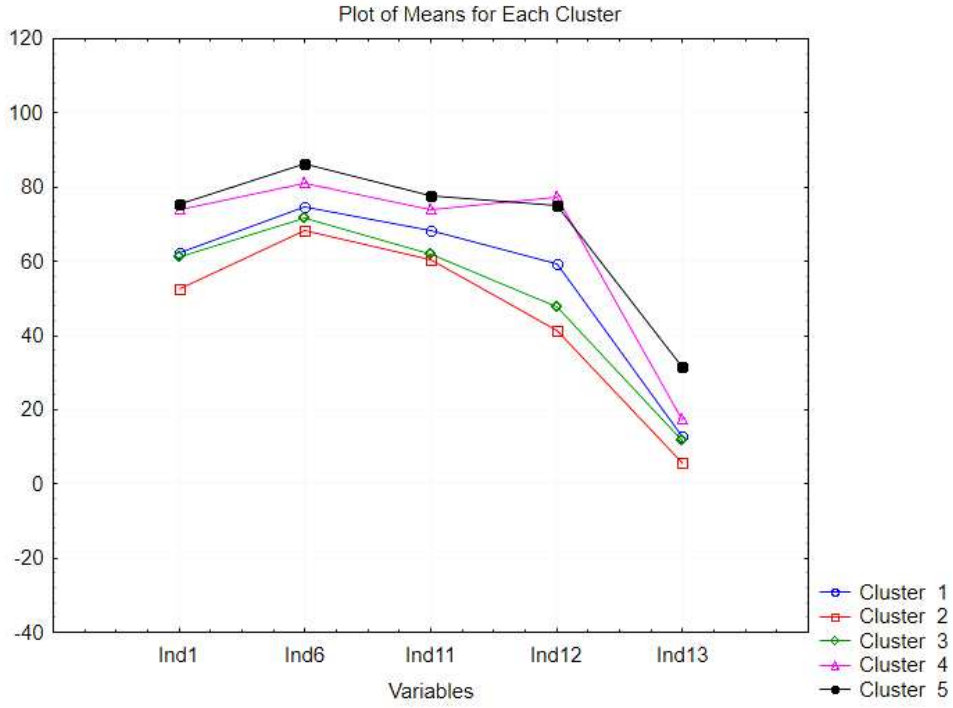


**Figure 4.** Average values of clusters obtained in 2024

**Table 8.** Qualitative assessment of clustering performed using the k-means method in 2024

| Indicator | Between SS | Df | Within SS | df | F-test | p |
|---|---|---|---|---|---|---|
| Inst | 2562.89 | 4 | 429.76 | 31 | 46.22 | 0.000 |
| Skills | 1370.65 | 4 | 604.67 | 31 | 17.57 | 0.000 |
| Busin | 1528.26 | 4 | 370.22 | 31 | 31.99 | 0.000 |
| Innov | 7364.01 | 4 | 857.08 | 31 | 66.59 | 0.000 |
| ae_demand | 2396.55 | 4 | 654.65 | 31 | 28.37 | 0.000 |

tries combine strong institutions, advanced innovation systems, high-quality skill formation, and consistently high participation in adult education. Their positions indicate not only a strong recovery after the pandemic period but also a structurally embedded model of lifelong learning linked to innovation-driven competitiveness.

The fourth cluster also consists exclusively of high-income countries and demonstrates consistently high values across the clustering indicators. At the same time, this cluster appears somewhat more specialized, with particularly strong positions in innovation-oriented and institutional dimensions, while remaining slightly below the fifth cluster in some broader competitiveness indicators.

The first cluster includes countries with mixed but generally intermediate competitiveness profiles. These economies demonstrate noticeable improvements in institutional and educational indicators compared with earlier periods, but their average values remain below those observed in the two leading clusters.

The third cluster also brings together countries with mixed socio-economic characteristics. Its average values are broadly comparable to those of the first cluster, although these countries tend to display somewhat weaker institutional and innovation positions and more moderate adult learning participation.

The second cluster, which includes Ukraine, is characterized by the lowest average values of competitiveness determinants and adult education demand. This suggests the persistence of structural barriers to the development of lifelong learning and innovation-oriented growth in the lower-performing part of the European sample. In the


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case of Ukraine, this position is additionally associated with the severe socio-economic disruptions caused by the full-scale war, which has constrained institutional capacity, business development, and the functioning of adult education systems despite growing demand for reskilling and adaptive learning.

The identified cluster configuration for 2024 reflects the persistence of structural differences among European countries in institutional development, innovation capacity, and participation in adult education systems. While economically advanced countries continue to demonstrate strong and stable competitiveness positions, other groups of countries remain characterized by more moderate or constrained development trajectories.

The identified clusters should be interpreted as comparative groupings of countries with similar combinations of competitiveness determinants and adult education demand at a given point in time. Accordingly, changes in cluster composition across the benchmark years do not indicate inconsistency of the method; rather, they reflect changes in the relative positions of countries within the European sample. In the present study, the hierarchical Ward procedure consistently identified a five-cluster solution for each benchmark year, while ANOVA confirmed the statistical significance of the selected variables, which supports the robustness of the obtained clustering results. The observed transitions of countries between clusters are associated with changes in key underlying factors, including institutional quality, skill formation systems, business development, innovation capacity, and participation in adult education. Thus, clustering makes it possible not only to identify groups of countries with similar structural profiles, but also to trace how these profiles evolve over time. Therefore, the value of clustering in this study lies in its ability to reveal both the structural differentiation of European countries and the dynamics of their transformation.

In order to summarize the results of the clustering analysis and highlight the structural characteristics of the identified groups, it is useful to consider the clusters from a broader analytical perspective. In particular, attention should be paid to the socio-economic profiles of the clusters, the group of countries that form their relatively stable core, and the countries whose cluster affiliation changed during the period under analysis. These structural characteristics of the clusters identified for the period 2015–2024 are presented in Table 9.

Thus, the results of the study reveal changes in the cluster affiliation of individual countries at different points in time, reflecting transformations in their relative positions within the European socio-economic space in terms of competitiveness determinants and demand for adult education. At the same time, a group of countries whose cluster affiliation remained relatively stable throughout the entire observation period can be identified. In particular, countries such as Austria, Belgium, Ireland, Luxembourg, Germany, and France consistently demonstrate high values of institutional development, innovation capacity, and participa-

**Table 9.** Structural characteristics of clusters of European countries according to competitiveness determinants and demand for adult education in 2015–2024

| Cluster | Socio-economic profile | Core countries | Countries with changing cluster affiliation |
|---|---|---|---|
| Cluster 1 | Highly competitive economies with strong institutional environments and high participation in adult education | Austria, Belgium, Germany, France, Ireland, Luxembourg | Finland, the Netherlands |
| Cluster 2 | Economies with developed human capital and moderate innovation potential | Estonia, Cyprus, Latvia, Malta | Italy, Slovenia, Lithuania |
| Cluster 3 | Countries with intermediate competitiveness indicators and moderate adult education participation | Spain, Portugal, the Czech Republic, Poland | Croatia, Slovakia |
| Cluster 4 | Northern European economies characterized by strong innovation systems and advanced lifelong learning institutions | Denmark, Sweden, Norway, Finland | Iceland |
| Cluster 5 | Countries with relatively low competitiveness determinants and limited participation in adult education | Bulgaria, Romania, Serbia, Hungary, Ukraine | Greece, North Macedonia, Montenegro, Turkey |

tion in adult education. The stability of their cluster positions reflects the sustained strength of their socio-economic systems and the long-standing institutional support for lifelong learning.

Other clusters are characterized by a more dynamic structure and demonstrate periodic regrouping of countries as a result of gradual convergence or divergence in socio-economic characteristics and parameters of adult education development. These shifts reflect differences in the pace of institutional modernization, innovation development, and the expansion of adult learning systems across European economies.

Throughout the analyzed period, Ukraine belonged to the cluster characterized by comparatively lower values of competitiveness determinants and participation in adult education. The composition of this cluster varied across years and included, among others, Bulgaria, Greece, North Macedonia, Romania, and Serbia. Such variability indicates a relatively unstable configuration of this group and reflects ongoing transformations in the economic development trajectories, adult education systems, and broader socio-economic conditions of the respective countries.

## 4. DISCUSSION

The results obtained are consistent with established approaches in the literature, according to which adult education, skills development, and economic competitiveness are formed as interrelated but structurally heterogeneous processes. In particular, the differentiation of European countries in terms of the combination of institutional characteristics, skill development, innovation potential, and demand for adult education corresponds to the findings of studies emphasizing the systemic nature of human capital and its role in shaping competitive advantages (Green, 2006; Jarvis, 2007).

Similar to the results of Denkowska et al. (2020) and Bulut et al. (2022), the cluster structures identified for the period 2015–2024 show that countries with high competitiveness scores do not constitute a homogeneous group. Even among economies with high GDP per capita, different combinations of institutional quality, innovative development, and adult participation in learning can be observed. This confirms the conclusions of Dima et al. (2018) that competitiveness in the European space is shaped not only by macroeconomic factors but also by qualitative differences in human capital development.

The results obtained in this study should also be interpreted in relation to the findings of Kuzior et al. (2023) and Onopriienko (2023). In particular, Kuzior et al. (2023) argue that lifelong learning acts as an important factor in strengthening innovative potential and sustainable development, which is generally consistent with the results of the present study, where adult education demand is closely associated with broader dimensions of competitiveness, especially innovation capacity, business development, and institutional quality. At the same time, Onopriienko (2023) applied a similar cluster approach to the analysis of European countries for the period 2012–2021 and demonstrated that determinants of adult education demand and competitiveness form relatively stable yet internally differentiated country groupings. At the same time, the present study is not limited to reproducing previous results. First, it extends the time horizon to 2024, which makes it possible to capture structural changes that could not be fully reflected in earlier research, particularly those related to the pandemic aftermath, accelerated digitalization, and the geopolitical and economic disruptions caused by the full-scale war in Ukraine. Second, the current study places stronger emphasis on the dynamic interpretation of cluster transitions, allowing countries' movements between clusters to be treated not as random regrouping, but as a reflection of changes in institutional capacity, innovation performance, and the functioning of lifelong learning systems. Thus, this paper develops and updates the earlier methodological approach rather than duplicating it, and provides a more relevant empirical picture of the contemporary European landscape of adult education demand and competitiveness.

At the same time, the results elaborate on the approaches presented by Rubenson and Desjardins (2009) and Saar et al. (2013), where the main focus was on institutional barriers to adult participation in learning. The cluster structure obtained in this


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study allows the demand for adult education to be interpreted not as an isolated indicator, but as a component of broader national competitiveness models, within which high or low levels of adult participation in learning are combined with corresponding characteristics of the business environment and innovative development.

The results also correspond with studies that highlight the unevenness of transformations in adult education across European countries (Holford et al., 2014; Mikulec, 2018). The migration dynamics of individual countries between clusters during 2015–2024 indicate that the positions of countries within the European space are not static and reflect gradual changes in the combination of institutional and educational characteristics. This conclusion is consistent with the approaches of Németh (2010) and Mayo (2009), who view the development of adult skills and education as a long-term, cumulative process.

At the same time, the results also reflect the influence of recent structural shocks, particularly the COVID-19 pandemic, which accelerated the digitalization of education systems and expanded access to flexible and online learning formats across Europe. These processes have contributed to noticeable changes in adult education participation and skill development in several countries, reinforcing the role of lifelong learning in maintaining competitiveness in rapidly changing socio-economic conditions.

Unlike studies in which competitiveness analysis is based primarily on aggregate indices or individual variables (Dima et al., 2018; Bulut et al., 2022), the results obtained allow European countries to be interpreted in terms of typical combinations of key characteristics. This approach does not replace traditional index or econometric methods, but complements them, creating a convenient empirical basis for intergroup comparison and further research.

Particular attention should be paid to the stability of the positions of groups of countries with high levels of institutional development and demand for adult education throughout the analysis period, which is consistent with the conclusions of Gaimard and Kroll (2014) regarding the role of institutional stability in ensuring effective investment in human capital. At the same time, groups of countries with lower values of the relevant indicators demonstrate greater variability in composition, confirming the thesis about the sensitivity of adult education systems to economic and structural changes (Desjardins et al., 2006).

Overall, the results complement existing approaches to the analysis of adult education and competitiveness, allowing these characteristics to be considered in relation to each other in a European context. Summarizing the results in the form of country groupings creates a convenient analytical basis for comparative analysis aimed at identifying differences and similarities in the combination of institutional, educational, and economic characteristics. This expands the possibilities for further research focused on studying the dynamics of human capital development and competitiveness in European countries.

## CONCLUSION

The study aimed to conduct a comparative analysis of European countries based on the relationship between economic competitiveness and the demand for adult education by grouping countries according to the similarity of their socio-economic characteristics. Achieving this objective made it possible to develop an empirical analytical framework for identifying typical differences between European countries in terms of institutional development, innovation capacity, skill formation, and participation in lifelong learning.

The results show that the combination of competitiveness determinants and adult education indicators forms a clear cluster structure of European countries for the benchmark years 2015, 2020, and 2024, with five clusters identified for each period.

The analysis revealed the existence of a stable core of highly competitive European economies, including Austria, Belgium, Germany, France, Ireland, Luxembourg, Denmark, the Netherlands, Norway, Sweden, Finland, and Switzerland, which consistently demonstrate strong institutional environments, high innovation capacity, and high participation in adult education.

At the same time, several countries occupy intermediate positions within the cluster structure, including Spain, Italy, Portugal, the Czech Republic, Poland, Slovenia, and Estonia, reflecting moderate levels of competitiveness and adult education participation.

Throughout the analyzed period, Ukraine remained within the cluster characterized by the lowest values of competitiveness determinants and adult education demand, together with countries such as Bulgaria, Romania, Serbia, and North Macedonia. This position reflects persistent structural constraints in economic development and adult education systems, which have been further intensified by the socio-economic disruptions caused by the full-scale war.

Overall, the results demonstrate that the joint consideration of competitiveness determinants and adult education demand provides a useful analytical basis for identifying structural differences between European countries and for conducting further comparative research on human capital development and competitiveness.

## AUTHOR CONTRIBUTIONS

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# APPENDIX A

**Table A1.** Array of input data on the study of system relationships in the chain "demand for adult education – competitiveness of the country" (extract)

| Year | ID | Inst | infr | ict | Macr | health | skills | p_ rmark | lab_ mark | fin_ syst | m_size | busin | innov | ae_ demand | gci | GDP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2015 | 1 | 76.1 | 76.6 | 76.5 | 95.6 | 95.1 | 74.5 | 66.1 | 65.5 | 78.8 | 66.4 | 78.8 | 70.2 | 15.7 | 5.1 | 1 |
| 2016 | 1 | 76.6 | 78.3 | 76.2 | 97.7 | 95.2 | 75.6 | 66.7 | 65.7 | 77.5 | 66.8 | 78 | 71.3 | 17.5 | 5.2 | 1 |
| 2017 | 1 | 76.1 | 81.4 | 75.4 | 98.1 | 95.5 | 76.5 | 67.7 | 65.1 | 76.6 | 66.4 | 77.9 | 72.4 | 18.9 | 5.3 | 1 |
| 2018 | 1 | 75.7 | 85.1 | 74.3 | 98.2 | 96.7 | 77.1 | 67.9 | 64.2 | 74.3 | 66 | 78.3 | 73.1 | 17.2 | 5.3 | 1 |
| 2019 | 1 | 74.2 | 88.7 | 75.9 | 100 | 95.1 | 78.6 | 66.2 | 66.9 | 75.2 | 65.3 | 79.1 | 74.4 | 17.4 | 5.4 | 1 |
| 2020 | 1 | 73.5 | 89.2 | 73.2 | 99.6 | 93.6 | 78.9 | 65.8 | 66 | 75.7 | 65 | 77.2 | 75.2 | 14.8 | 5.4 | 1 |
| 2021 | 1 | 74.1 | 89.4 | 73.6 | 99.8 | 94.1 | 79.2 | 66 | 66.7 | 77 | 65.3 | 78.1 | 76 | 17.4 | 5.4 | 1 |
| 2022 | 1 | 74.5 | 90.1 | 74.2 | 99.5 | 94.4 | 79.8 | 66.4 | 67.1 | 77.5 | 65.8 | 78.9 | 76.8 | 18.1 | 5.5 | 1 |
| 2023 | 1 | 75 | 90.7 | 75 | 99.6 | 94.8 | 80.4 | 66.9 | 67.5 | 78.2 | 66.2 | 79.6 | 77.5 | 18.7 | 5.6 | 1 |
| 2024 | 1 | 75.3 | 91.2 | 76.1 | 99.7 | 95 | 81 | 67.2 | 68 | 78.8 | 66.6 | 80.3 | 78.3 | 19.3 | 5.7 | 1 |
| 2015 | 2 | 75.6 | 80.1 | 65.4 | 95.8 | 84.5 | 75.4 | 64.6 | 55.4 | 81.4 | 68.8 | 77 | 72.8 | 12.6 | 5.2 | 1 |
| 2016 | 2 | 74.3 | 78.6 | 68.6 | 95.7 | 85.7 | 74.3 | 64.3 | 56.1 | 81.7 | 67.1 | 77.1 | 71.4 | 13.1 | 5.3 | 1 |
| 2017 | 2 | 77.8 | 84.3 | 66.7 | 97.3 | 87.9 | 77.6 | 64.7 | 55.2 | 80.6 | 58.2 | 75.6 | 71 | 13.8 | 5.2 | 1 |
| 2018 | 2 | 79.2 | 85.2 | 65.4 | 98.7 | 93.2 | 78.6 | 65.1 | 55.6 | 76.5 | 69.2 | 72.5 | 70.1 | 14 | 5.4 | 1 |
| 2019 | 2 | 69.1 | 87.2 | 66.8 | 99.6 | 92.4 | 79.1 | 63.3 | 54.5 | 78.6 | 68.8 | 73.9 | 71.4 | 12.9 | 5.3 | 1 |
| 2020 | 2 | 68.6 | 88.5 | 65.7 | 99.7 | 90.1 | 79.8 | 63 | 54 | 79.2 | 68 | 73 | 72.3 | 12.3 | 5.4 | 1 |
| 2021 | 2 | 69.6 | 89.2 | 66.1 | 88.9 | 90.3 | 80 | 64.3 | 55.6 | 79.8 | 68.6 | 73.4 | 73.2 | 15.2 | 5.4 | 1 |
| 2022 | 2 | 70.1 | 89.9 | 66.8 | 90.1 | 90.7 | 80.4 | 64.8 | 56.2 | 80.2 | 69.1 | 74.1 | 73.9 | 15.8 | 5.5 | 1 |
| 2023 | 2 | 71 | 90.5 | 67.5 | 91.4 | 91.2 | 81.1 | 65.4 | 56.8 | 80.9 | 69.5 | 74.9 | 74.6 | 16.2 | 5.6 | 1 |
| 2024 | 2 | 71.6 | 91.2 | 68.3 | 92 | 91.6 | 81.8 | 66 | 57.4 | 81.5 | 70 | 75.6 | 75.4 | 16.9 | 5.7 | 1 |
| 2015 | 3 | 51.8 | 62.1 | 75 | 87.1 | 73.2 | 63.4 | 55.6 | 58.8 | 62.3 | 56.6 | 55.6 | 45.6 | 16.9 | 4.3 | 0 |
| 2016 | 3 | 52.5 | 64 | 74.5 | 88.2 | 75.1 | 65.1 | 56.7 | 59.3 | 61.1 | 54.1 | 58.7 | 45.1 | 18.7 | 4.4 | 0 |
| 2017 | 3 | 53.3 | 67.8 | 73.2 | 88.9 | 77.6 | 65.6 | 57 | 61.5 | 59.8 | 54.2 | 59.6 | 45 | 19.9 | 4.4 | 0 |
| 2018 | 3 | 54.1 | 70.1 | 70.2 | 89.1 | 79.6 | 65.2 | 57.1 | 62.1 | 58.1 | 54 | 60.2 | 44.5 | 17.1 | 4.5 | 0 |
| 2019 | 3 | 56.7 | 70.7 | 73.2 | 90.3 | 78.1 | 67.8 | 55.3 | 65.2 | 60.6 | 54.9 | 61.5 | 45 | 18.5 | 4.5 | 0 |
| 2020 | 3 | 55.8 | 71.4 | 70.1 | 89.7 | 76.7 | 69.3 | 52.3 | 65 | 61.2 | 53.1 | 60.2 | 46.8 | 18.9 | 4.6 | 0 |
| 2021 | 3 | 56.7 | 71.8 | 70.2 | 89.8 | 76.9 | 70 | 52.8 | 65.8 | 61.7 | 51.7 | 61 | 47.8 | 19.8 | 4.6 | 0 |
| 2022 | 3 | 57.3 | 72.5 | 71 | 90 | 77.5 | 70.5 | 53.1 | 66.2 | 62 | 52.2 | 61.5 | 48.6 | 20.2 | 4.7 | 0 |
| 2023 | 3 | 58 | 73 | 72.1 | 90.2 | 78.1 | 71.3 | 53.8 | 66.7 | 62.8 | 52.6 | 62.3 | 49.4 | 20.7 | 4.8 | 0 |
| 2024 | 3 | 58.7 | 73.8 | 73 | 90.5 | 78.7 | 72 | 54.4 | 67.2 | 63.5 | 53 | 63.1 | 50.2 | 21.3 | 4.9 | 0 |
| 2015 | 4 | 54.4 | 74.2 | 64.4 | 72.2 | 91.2 | 61.4 | 55 | 48.8 | 53.2 | 60.4 | 55.3 | 44.8 | 5 | 4.1 | 0 |
| 2016 | 4 | 53.3 | 75.1 | 64.5 | 72.8 | 91.4 | 64.3 | 55.2 | 50.8 | 51.1 | 61.2 | 55 | 44.1 | 4.7 | 4.2 | 0 |
| 2017 | 4 | 52.3 | 75.3 | 64.1 | 73.2 | 92.3 | 66.5 | 55.4 | 51.6 | 56.6 | 60.7 | 56.1 | 43.9 | 4.7 | 4.3 | 0 |
| 2018 | 4 | 49.7 | 75.6 | 64.3 | 73.4 | 94.6 | 68.7 | 55.3 | 53.4 | 50.7 | 60 | 57.8 | 43.6 | 4.2 | 4.3 | 0 |
| 2019 | 4 | 50.8 | 77.8 | 65.1 | 75.2 | 93.7 | 70.1 | 53.7 | 52.9 | 49.1 | 59.7 | 58.6 | 44.8 | 4.4 | 4.4 | 0 |
| 2020 | 4 | 51.5 | 78.3 | 64.5 | 74.8 | 90.3 | 70.6 | 51 | 52 | 50 | 57.2 | 57.8 | 46.1 | 4 | 4.4 | 0 |
| 2021 | 4 | 52.1 | 78.9 | 64.8 | 75.2 | 90.6 | 70.9 | 52.4 | 52.8 | 50.6 | 58.8 | 58.1 | 47.8 | 3 | 4.4 | 0 |
| 2022 | 4 | 52.8 | 79.6 | 65.4 | 75.8 | 91.1 | 71.6 | 52.9 | 53.5 | 51.2 | 59.2 | 58.9 | 48.5 | 3.6 | 4.5 | 0 |
| 2023 | 4 | 53.6 | 80.2 | 66.1 | 76.4 | 91.5 | 72.3 | 53.5 | 54 | 51.8 | 59.7 | 59.6 | 49.2 | 4 | 4.6 | 0 |
| 2024 | 4 | 54.2 | 80.9 | 66.9 | 77 | 92 | 73 | 54.1 | 54.8 | 52.4 | 60.2 | 60.4 | 50 | 4.5 | 4.7 | 0 |

*Note:* * where 1 is Austria, 2 is Belgium, 3 is Bulgaria, 4 is Greece etc. ** where 1 – countries whose GDP per capita exceeds 40 thousand dollars, 0 – countries whose GDP per capita does not exceed 40 thousand dollars, USD.


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