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Categorization of the EU Member States in the Context of Selected Multicriteria International Indices Using Cluster Analysis

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Abstract: The main aim of the paper was to analyse the economic and social development of the European Union (EU) member states (28 countries) on the basis of selected five multicriteria indices (the Global Competitiveness Index, the Economic Freedom Index, the Global Innovation Index, the Corruption Perceptions Index, the Human Development Index). To perform settled aim, a multidimensional classification of EU countries for years 2011 and 2018 using cluster analysis was realized. The purpose of the analysis was to categorize the individual EU countries into clusters and to find out to what extent the position of EU member states has changed in terms of selected international indices over the analysed period. Based on the findings, it is arguable that a major part of the EU member states cluster into the same groups based on the selected indices assessment, regardless of the time period. However, six countries (Czech Republic, Estonia, Germany, Latvia, Lithuania, and United Kingdom) improved their position during the period under review and ranked into the cluster of more prosperous countries in 2018. The rate of change (improvement) was quantified at the level of 21.43%. Based on the results, Latvia and Lithuania were the most similar countries in terms of economic prosperity (Euclidean distance reached the level of 3.08), while the least similar countries were Greece and Sweden (Euclidean distance reached the level of 70.8). Declining Euclidean distances indicate that economic disparities of the individual EU countries have decreased in the period under review. This paper aims at developing the research to find out how, besides hierarchy, we can analyse the EU member states from the perspective of various multicriteria indices. The four proposed clusters could be used as a starting point for future policy reforms, pointing to the weaknesses of various countries.

Keywords: Cluster analysis, economic development, EU member states, international indices, multidimensional classification

JEL Classification: E60, O11

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Introduction

In recent years, the turbulent development of the world economy can be observed, followed by many unexpected phenomena and problems determining the economic cycle of all countries. The global economy must face increasing risks and uncertainties, while the economic growth of countries stays considerably non-constant. Kvizda and Solnicka (2019) concluded that in unstable environments a risk minimization strategy is often chosen, and wide-scale changes are extremely uncommon. Moreover, the global business environment is evolving faster with increasing time, and it constantly comes to social, technological, and other changes. Thus, it is important to react to these changes promptly and ideally predict them (Gallo and Tomcikova, 2019). The debate on the issue of economic development in the European Union (EU) countries includes topics related to the digitalization of the world's economy, free international trade, innovation, and climate. The EU is constantly striving to build an open global economy, as well as to support international economic cooperation to ensure sustainable economic growth.

Assessing and comparing the economic situation of countries within a certain political-economic arrangement is a rather complex and challenging process. As reported by Tomes (2017), the assessment is made more complicated by the fact that differences between Western and Eastern European countries are still considerable in many areas (e. g. product innovation, environmental protection, in the application of new policies or reform initiatives). According to Sira et al. (2017), there are many organizations that evaluate the competitiveness or other aspects of the countries (Statistical Office, Eurostat, World Economic Forum, and other institutions). One of the best approaches to assessing countries is to use different international indices. Many global organizations and institutions are devoted to annual evaluations of countries against a variety of criteria that are transformed to scores and results and are presented in reports.

In a complex world, many variables affect the development and similarity of countries. It is problematic to determine what precisely is driving the economy of a country. Economic factors, institutions, culture, and corruption are all believed to play a role. In our previous studies, we analysed the development of countries' competitiveness from different perspectives based on only one multicriteria index (e.g. Kiselakova et al. 2018a), two indices (e.g. Kiselakova et al. 2018b) or three indices (e.g. Kiselakova et al. 2019). We decided to carry out this research using up to five multicriteria indices, which include several other important aspects and criteria that significantly affect the economic growth and development of countries. The main aim of the paper was to evaluate the socio-economic development of the European Union (EU) member states. To perform multidimensional classification of EU countries for years 2011 and 2018, a cluster analysis was used. The purpose of the analysis was to find out to what measure the position of EU member states has changed in terms of selected international indices over the analysed period.

Literature review

In the context of the ongoing globalization processes, policymakers require quantitative knowledge to design effective and targeted policies (Stefko, Gavurova, and Kocisova, 2018). At the macroeconomic level, indices serve as "indicators of country's performance" that can help the governments to solve the most significant challenges and im-

plement a sustainable economic development strategy. Many research studies and publications are currently addressing the issue of country evaluation using one or more international indices. According to Roy (2018), the Global Competitiveness Index (GCI) is the adequate tool for evaluating the competitive position of a country. The study was innovative in the sense that it exclusively examined the impact of all the pillars categorized into three sub-indices on GCI, which is expected to add value in the literature of global competitiveness. As reported by Kiselakova et al. (2018b), the issue of competitiveness and sustainable economic growth of countries is constantly at the center of interest. The informative value of GCI is also analysed by Workie and Hekelova (2016). Authors argue that it would be more informative to follow the rankings of countries according to sub-indices (based on disaggregated data) rather than overall ranking. Bucher (2018) states that an analysis of European countries in line with only the GCI helps to reveal the specifics of the existing regional socio-economic differentiation compared to averaged European data.

The paper of Karateev (2017) aimed to analyse the Index of Economic Freedom (EFI) in the selected countries. The correlation analysis between EFI and other social, economic, and political indices was confirmed. Greater economic freedom correlates with higher per capita incomes and overall wellbeing, including factors such as health, education, innovation, and democratic governance. However, these measures often fail to capture important dimensions of life quality related to the strength of social networks, quality of education, personal health, and psychological wellbeing. So, Nikolaev (2014) explored the relationship between economic freedom and more than twenty indicators of quality of life (through the Your Better Life Index). Findings show that economic freedom is strongly and positively correlated with most of these areas quantifying wellbeing in life. Economic freedom, as stated by Vrabec and Marek (2016), is a necessary condition for democratic development, prosperity, and other positive outcomes.

According to Sohn, Kim, and Jeon (2016), innovations can be considered as the most important aspect of competitiveness. The Global Innovation Index (GII) was proposed to observe the innovation capability of individual countries using input and output factors. Using the GII data, authors discovered that business sophistication and infrastructure have the strongest direct effects on improving the innovation capabilities of countries. Jankowska, Matysek-Jedrych, and Mroczek-Dabrowska (2017) presented the paper related to the national innovation systems also using the GII as the important economy efficiency metric. The research question was founded on the assumption that higher innovation input leads to the higher innovation output attained by a country. The authors used cluster analysis to verify their assumption, referring to 228 countries. Using regression and cluster analysis, Stefko et al. (2019) analysed the impact of the innovation activity (the GII index) on healthcare satisfaction as well as its impact on maturity (the HDI index) in the selected OECD countries. A significant impact was reflected in both assumptions.

The country's economic assessment also involves monitoring the level of Foreign Direct Investment (FDI) development in relation to the corruption problem. An important part of the research is to observe the relationship between FDI and the Corruption Perceptions Index (CPI). Ngoc, Hai and Chinh (2018) investigated how different perceptions of CPI impact upon one of the fundamental decisions made by foreign investors, the

choice of FDI location within the selected host country. A clear positive relationship between CPI and FDI was proved.

Physical and spiritual health are enduring and vital values that are at the top of the hierarchy of needs, which have a great impact on the quality of labour resources, labour productivity, production of the country's national product, and finally, for creation of a national wealth of the states (Morozov and Ziganshina, 2018). According to Ivankova et al. (2019), the greatest emphasis is placed on the differences between health care financing systems. Many studies explore the relationship between economic growth and the level of human development measured by the Human Development Index (HDI). Findings show that economic growth considerably contributes to human development and vice versa (Khan, Ju, and Hassan, 2018). Human development from the point of view of the higher education quality was addressed by Jovovic, Draskovic, and Jovovic (2016). According to the authors, the decline in higher education quality is influenced mainly by low-quality level of human resources, culture, and information technology.

In this regard, it is necessary to monitor several aspects of economic development at the same time. Every international index evaluates different economic areas, so it is important to apply various indices within the economic evaluation process of a country. An example of this is a research paper published by Vevere, Zvirgzdina, and Linina (2017). The authors used several above-mentioned indices (such as the KOF Index of Globalization, CPI, GCI, and GII) that characterize the business environment for evaluation of Baltic countries. As reported by Huttmanova and Valentiny (2019); Huttmanova, Novotny, and Valentiny (2019), in the process of sustainable development of the EU countries, it is essential to analyse the components of sustainable development. The authors explored how the selected HDI, ESHDI and EPI indexes reflect developments in the cyclical economy, which has only recently become one of the approaches to achieving sustainable development and is primarily linked to its economic and environmental aspects. The importance of multicriterial analysis in the context of increasing the countries' economic prosperity was also confirmed by Rusu and Dornean (2019). The authors were focused on investigating the selected economic areas such as competitiveness, innovations, and macroeconomic environment. In research, they considered a sample of 28 EU countries from 2011 to 2017, and the empirical investigation confirmed significant positive relations between variables.

Research methodology

In the current era of ever-increasing globalization and internationalization, the economies of the EU member states are still developing different trends, with some countries showing similar economic results. This fact served as the main stimulus for the analysis.

This paper presents an attempt to analyse the economic and social development of EU member states on the basis of international indices (GCI, EFI, GII, CPI, and HDI). To perform settled aim, a cluster analysis was applied. A multidimensional classification of EU countries was realized for years 2011 and 2018. The purpose of the analysis was to categorize individual EU countries into clusters and to find out to what measure the position of EU member states has changed in terms of selected international indices over the period analysed. The partial intention of the paper was to identify characteris-

tics of the clusters, as well as to suggest arrangements leading to the elimination of economic disparities of the EU countries.

The research question (RQ) was formulated in accordance with the set objective of the paper: To what extent has the position of EU Member States changed in terms of selected international indices (GCI, EFI, GII, CPI, and HDI) over the period analysed?

Data description

The economic development of the EU member states has been quantified using five selected composite indices annually issued by world-renowned organizations and institutions. All analysed indices represent comprehensive, integrated tools for assessing the level of economic prosperity in different areas of research. We strived to include key economic aspects in the research analysis and examine the change, not development. We decided to compare 2011 with 2018 (7 years' time period) because the methodology for computing the Global Innovation Index had changed in 2011. Furthermore, some minor changes in methodology were made in the case of other indices as well. Therefore, it was not possible to compare a longer time period. To meet the data completeness condition and to adhere to the correctness of the comparison of the results, we had to make two adjustments:

The score ranges of individual indices vary. Such differences complicated the comparisons of the countries. Therefore, we decided to transform the original index scores by a simple adjustment to a score moving in the same range (in this case, a range from 0 to 100). These adjustments need to be applied to GCI and HDI, as follows:

$$I_A = (I_B / 7) * 100 \quad \text{[in the case of GCI]} \tag{1}$$

$$I_A = I_B * 100 \quad \text{[in the case of HDI]} \tag{2}$$

where:
I_A *– adjusted index,*
I_B *– basic index.*

The theoretical and methodological framework of selected indices is characterized in the following part of the paper. Individual composite indices provide a complex tool for assessing a certain economic aspect; however, on the other hand, it is quite challenging to identify specific determinants. For the reason of the availability of reports and with the intention of obtaining a diverse perspective for the analysis of EU countries, we focused on the following indices: GCI, EFI, GII, CPI, and HDI.

Global Competitiveness Index

The GCI has been measuring the factors reflecting drive long-term growth and prosperity, helping to design the economic growth strategies. GCI framework consists of 12 pillars divided into 3 sub-indices (Schwab et al., 2017):

a) Basic requirements (1^{st} – 4^{th} Pillar): Institutions, Infrastructure, Macroeconomic environment; Health and primary education (Σ 45 indicators);

b) Efficiency enhancers (5^{th} – 10^{th} Pillar): Higher education and training, Goods market efficiency, Labour market efficiency, Financial market development, Technological readiness, Market size (Σ 53 indicators);
c) Innovation and sophistication factors (11^{th} – 12^{th} Pillar): Business sophistication, R&D Innovation (Σ 16 indicators).

Economic Freedom Index

The EFI focuses on 4 key aspects measured by 12 specific components of the economic and entrepreneurial environment over which governments exercise typically policy control (Miller et al., 2018):

a) Rule of law (1^{st} – 3^{rd} component): Property rights, Judicial effectiveness, Government integrity (Σ 14 sub-factors);
b) Government size (4^{th} – 6^{th} component): Tax burden, Government spending, Fiscal health (Σ 6 sub-factors);
c) Regulatory efficiency (7^{th} – 9^{th} component): Business freedom, Labour freedom, Monetary Freedom (Σ 22 sub-factors);
d) Open markets (10^{th} – 12^{th} component): Trade freedom, Investment freedom, Financial freedom (3 integrated sub-factors).

Global Innovation Index

The GII conceptual framework is comprised of the overall GII score (the simple average of the Input and Output Sub-Index scores), the Innovation Input and Output Sub-Index (sub-indices consist of pillars), and the Innovation Efficiency Ratio (the ratio of the Output Sub-Index score to the Input Sub-Index score). Each pillar is divided into three sub-pillars, and each sub-pillar is composed of individual indicators, for a total of 80 indicators this year (Dutta et al., 2018):

a) Innovation Input Sub-Index (1^{st} – 5^{th}): Institutions (Political environment, Regulatory environment, Business environment), Human capital and research (Education, Tertiary education, Research & development), Infrastructure (ICTs, General infrastructure, Ecological sustainability), Market sophistication (Credit, Investment, Trade, competition & market scale), and Business sophistication (Knowledge workers, Innovation linkages, Knowledge absorption);
b) Innovation Output Sub-Index (6^{th} – 7^{th}): Knowledge and technology outputs (Knowledge creation, Knowledge impact, Knowledge diffusion), and Creative Outputs (Intangible assets, Creative goods and services, Online creativity).

Corruption Perceptions Index

The CPI is a global (180 countries/territories) aggregate index (up to 13 different data sources) capturing perceptions (experts/business executives) of corruption (abuse of power for private gain) in the public sector (public officials and institutions). Based on expert opinion from around the world, the CPI measures perceived levels of public sector corruption worldwide. A country's score can range from 0 to 100, whereas 0 indicates high levels of corruption, and 100 indicates low levels (Rubio et al., 2018).

Human Development Index

The HDI is a summary measure of average achievement in the key three basic dimensions of human development. The HDI was created to emphasize that people and their capabilities should be the ultimate criteria for assessing the development of a country, not economic growth alone. The HDI is the geometric mean of normalized indices for each of the three dimensions (Jahan et al., 2018):

a) Long and healthy life (Life expectancy index): the ability to lead a long and healthy life, measured by life expectancy at birth;
b) Knowledge (Education index): the ability to acquire knowledge, measured by mean years of schooling and expected years of schooling;
c) A decent standard of living (Gross national income index): the ability to achieve a decent standard of living, measured by gross national income per capita.

Methods

The term cluster analysis was first formulated in 1939 by R. C. Tryon. According to Scoltock (1982), cluster analysis is a multidimensional statistical method used for the classification of objects. It sorts units into groups (clusters) so that units belonging in the same group are more similar then objects from other groups. The cluster analysis is sensitive to the occurrence of outliers. Its purpose being, according to Koziak et al. (2014), to sort different objects into groups with the highest degree of association between objects in the same group and with a minimum degree of association between objects in different groups. The aim is to achieve as much similarity within groups as possible and make the individual groups as different as possible. As Rimarcik (2011) states, the important feature of cluster analysis is the fact that the classification of objects into individual clusters is based on a combination of multiple variables. Mura (2010) claims that when applying cluster analysis, one does not typically focus on the basic dimensions of the observed phenomena description (variables), but on the basic types of the phenomena observed as such (objects) and their homogeneity. As a rule, it is required that the number of clusters is substantially lower than the number of objects.

Kral et al. (2009) define the basic assumptions of using cluster analysis as follows:

- the absence of remote and missing values;
- standardization of variables (if necessary);
- only non-correlated variables enter the cluster analysis, i.e., if the correlation between variables does exist, it has to be removed (Kaiser-Meyer-Olkin criterion).

All the clustering methods are based on determining the similarities of objects that are to be assigned to the same cluster. The similarity is a measure determining to what extent objects might be considered similar. A significant part of these similarity measures is based on calculating the distances between the objects. The similarity of objects can be measured by different means, that can normally be classified into basic groups (association measures, distance measures (metrics) and correlation measures) with association and correlation coefficients representing the objects similarity rate, and metrics representing their dissimilarity (Trebuna and Halcinova, 2010). According to Meloun, Militky, and Hill (2012), distance measures are the most widely used measures based on the representation of objects in space, the coordinates of which form individual varia-

bles, and are used in statistical programs. The most commonly used distance measure is the Euclidean distance (ED), expressed by the equation:

$$ED_1(x_i, x_j) = \sqrt{\sum_{l=1}^{m}(x_{il} - x_{jl})^2} = \|x_i - x_j\| \quad (3)$$

where:
m – number of variables,
x_{il} – i_{th} coordinate in dimension "m",
x_{jl} – j_{th} coordinate in dimension "k".

Each distance between objects must fulfil the following properties for any triplet of x, y, of the objects considered:

- is nonnegative, i. e. d (x, y) ≥ 0;
- d (x, y) = 0 if x = y; (4)
- is symmetrical, i.e. d (x, y) = d (y, x);
- the triangular inequality is met, i.e. d (x, y) + d (y, z) ≥ d (x, z).

In consideration of data type used in the presented paper (worries about outliers), as well as, based on the literature review related to statistical methods applied in this research area, a simple Euclidean distance was applied (although, Squared Euclidean distance is used more often, in general). Cluster analysis methods are classified according to their objective, not the mathematical tools they employ. When choosing a clustering method, the nature of the original data should be taken into account. Ward's hierarchical clustering method is considered the best choice, as it combines objects into groups so that the inter-cluster dispersion is as low as possible. Thus, this method clearly distinguishes from all the others because it uses a dispersion analysis to determine the distance between clusters i.e., the minimum increase of the deviation squares sum from the cluster's average.

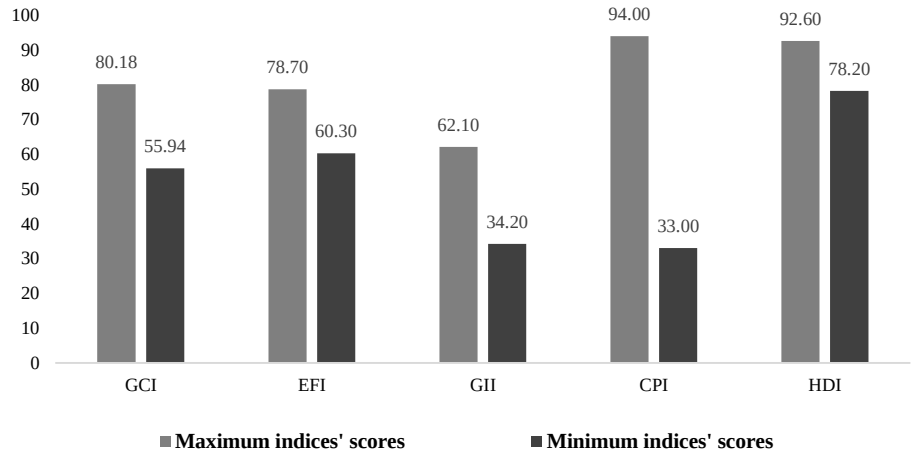
Results

The starting point for the actual categorization of the EU member states based on cluster analysis was the analysis and comparison of the socio-economic development of the EU member states in the context of the selected international indices. In the first part of the research, we decided to analyse the EU countries using selected indices at two set periods and to analyse the year 2011 in comparis sono the year 2018.

Evaluation of the EU member states ranking with regard to selected macroeconomic indices in 2011

In the following part of the paper, an analysis of the EU member states was made based on the resulting score of selected indices. An emphasis was put on comparing the best-performing countries to the worst-performing ones in 2011. See Figure 1 below for the resulting scores of the indices.

Figure 1. The indices' score results of EU member states in 2011



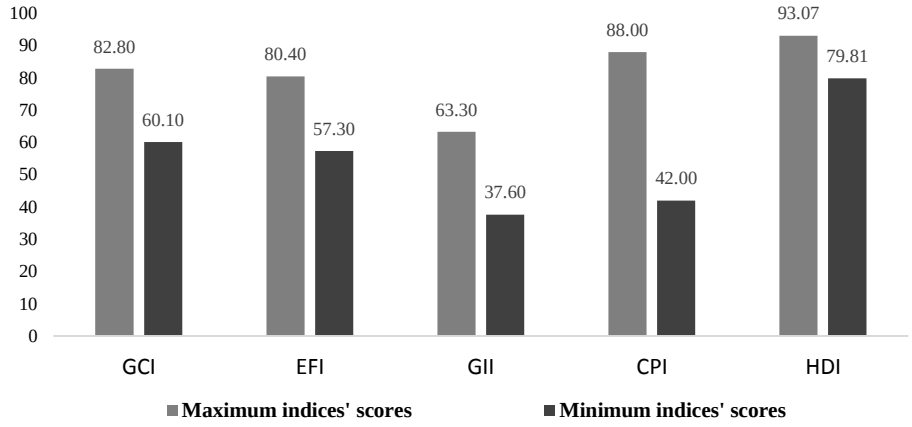
Source: own processing based on the data reports

The following section focuses on the analysis of individual EU countries in 2011 based on the selected indices. Several interesting facts have been found in the comparison of all indices after the compilation of all the rankings of the countries, namely that some countries have recorded the highest score simultaneously in several indices. An example of this is Denmark, which in 2011 was the EU leader in EFI and CPI rankings. On the other hand, Bulgaria achieved the lowest score among the EU countries for the CPI and HDI indices, and thus, in these two spheres, the country showed significant limits. Greece was also assigned a double negative ranking in the EU countries, namely in the GCI and GII indices. The highest score of the indices in which Greece was assigned a double negative rating was achieved by Sweden by GCI being 80.18 and GII 62.10. For the sake of completeness of the analysis, it is necessary to add that, according to the index score in 2011, the least economically free country in Europe was Italy, while Germany dominated Europe in the area of human development.

Evaluation of the EU member states ranking with regard to selected macroeconomic indices in 2018

Another part of the research is also devoted to the evaluation of EU member states from the point of view of the selected index scores. However, the analysis was carried out in 2018. The following Figure 2 presents a comparison of the score from the point of EU the best-performed and the worst-performed results.

Figure 2. The indices' score results of EU member states in 2018



Source: own processing based on the data reports

In the following part of the paper, the analysis focuses on the individual EU countries and their position in relation to the selected indices. On the basis of the scores of the countries, it can be stated that those dominating the ranking of two indices were identified once again. For instance, Germany was the leader in GCI and HDI. On the contrary, the lowest score achieved in those two indices was assigned to Bulgaria. No other country achieved a double position in any of the indices rankings. For the sake of completeness of the information for 2018, there are also other findings. Croatia was considered the least globally competitive EU country in 2018. When evaluating economic freedom, Greece ranked the last, while Ireland the first. In the area of innovation evaluation, the Netherlands has been a leader in the EU ranking, while the lowest level of innovation development has been indicated for Romania.

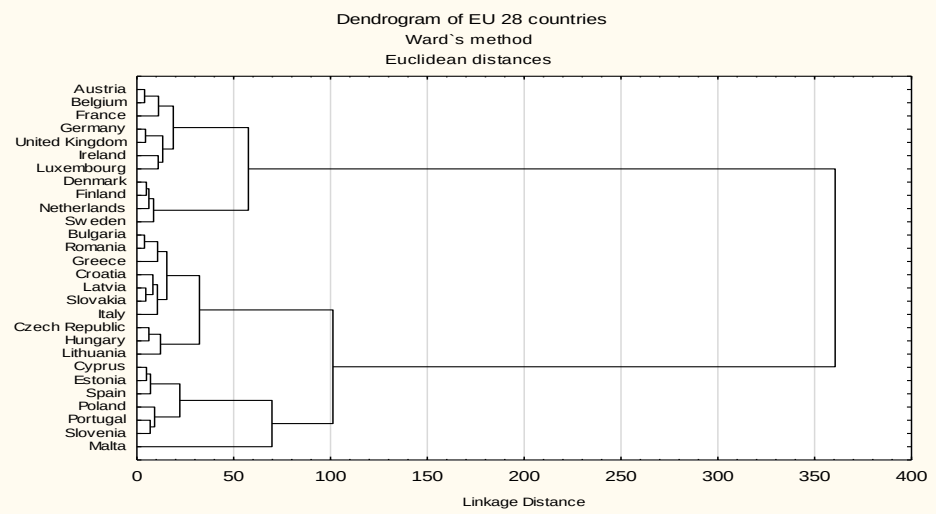
Categorization of EU member states by cluster analysis in 2011

So as to meet the set goal i.e., to find out the answer to the research question, in the next step of the research, we focused on the categorization of EU member countries by applying cluster analysis for 2011. A vital condition for the cluster analysis is the non-correlation of the input data. The correlation between the selected indices reached the value of 0.47, making it insufficient according to the KMO test, while well desirable for cluster analysis. The input data did not need to be standardized as all indices are expressed by score, thus eliminating any influence of the units. As mentioned in the methodological part of the paper, Ward's method of hierarchical clustering was employed in the analyses, whereby the ED between the variables was determined (mathematic formula number 3). The figure below shows the created clusters of EU countries in the form of a dendrogram for 2011.

When examining the dendrogram (Tree Diagram), we can observe the sequence of individual countries' interconnection with a whole based on similarity. As a rule of thumb, the greater the right-hand link (X-axis), the less the country is similar to the first cluster of countries. Thus, the resulting number of clusters is determined by the X-axis, which

indicates the distance at which a particular country has joined the particular cluster. Furthermore, the number of clusters can be estimated using intra/inter clusters' variance of individual variables. We decided to choose the number of clusters based on the dendrogram, so that units belonging to the same group were the most different from objects of other groups. Based on Figure 3, 4 clusters can be identified in 2011, namely:

Figure 3. Dendrogram of EU member countries in 2011



Source: own processing in STATISTICA

a) **Cluster 1**: ***"Economic leaders"*** – including four countries like Sweden, Netherlands, Finland, and Denmark. This cluster of countries was characterized by the highest score (average maximum) in all the indices. Such a result indicates that these countries were among the EU leaders in economic development. This cluster is made up of the countries that have significantly exceeded the EU average for the CPI and the GII index. At the same time, these countries deviated least from the EU average in the HDI. It is common knowledge that these Nordic countries are the Europe's most economically, socially, and innovatively developed countries, as confirmed by the results of our analysis. Economic prosperity, innovation activity, business environment conditions, as well as the social dimension, are high in these countries, as evidenced by the position of the countries in each ranking.

b) **Cluster 2**: "***Economically advanced countries***" – including seven countries like Luxembourg, Ireland, the United Kingdom, Germany, France, Belgium, and Austria. This group of countries did not reach any average minimums or maximums of individual indices; however, it acquired 2nd highest average scores in all indices simultaneously. Average values of the monitored indices within a given cluster of countries recorded values well above the EU average. Based on the average score compared to the EU average, the most significant difference between Cluster 1 countries was quantified for the CPI index. The country group index achieved the score higher by

24.87% on average. Conversely, the lowest difference at 3.99% was recorded for the HDI index. For the year 2011, we can hence label these countries as economically advanced, while admitting that these countries still have some limits in comparison with the most advanced EU countries.

c) **Cluster 3**: ***"Economically averaged countries"*** – including seven countries like Malta, Slovenia, Portugal, Poland, Spain, Estonia, and Cyprus. This cluster of countries (similar to Cluster 1) did not show any average minimums or maximums of individual indices; nevertheless, it obtained 2nd lowest average score in all the indices simultaneously. Yet the results suggest that the average index values in the given cluster of countries recorded values at about the same level as the EU average. The decline in the average score compared to the EU average ranged from 1.44% (for HDI) to 5.56% (for GCI). Thus, according to the results for 2011, it can be stated that countries belonging to this cluster formed the EU average in economic prosperity. Although the countries lagged behind the most developed ones, their starting position was not the worst among the EU countries.

d) **Cluster 4**: "***Economically limited countries***" – includes ten countries like Lithuania, Hungary, the Czech Republic, Italy, Slovakia, Latvia, Croatia, Greece, Romania, and Bulgaria. The present group consists of 10 countries (the largest cluster), meaning that these countries showed the highest level of similarity based on their overall score. Based on the results, we can conclude that Cluster 3 achieved average minimums across all indices. This means that, according to the evaluation of all the indices, these countries were among the economically weakest ones. By analysing the individual averages of the indices in the cluster, it was revealed that this group of countries was lagging behind the EU average most in the CPI and GII indices. On the other hand, these countries lagged behind the least in the HDI index evaluation. These examined countries indicated the largest limits in the economic dimensions under scrutiny.

The Distance matrix is the simplest result of the cluster analysis, and it is closely related to another result – the Amalgamation schedule (Figure 4). The algorithm first calculates all the EDs between the countries (and puts them in the Distance matrix) and only after arranging the distances in an ascending scale, it shows the Amalgamation schedule. A part of the Amalgamation schedule is presented below. It was not possible to show the entire sheet, as it contains 30 rows and 30 columns. Therefore, we only selected a part of it to explain what they express.

The Distance matrix determines the distances between objects (in our case countries) in a row and a column i.e., diagonally the distances attain the value of 0. The Amalgamation schedule basically expresses the same thing as the Distance matrix, with the first column showing the exact distance values at which the countries clustered. These distances are also aligned in ascending order. Based on the results of the Distance matrix and the Amalgamation schedule for 2011, we have revealed several findings.

Figure 4. Amalgamation schedule of the EU member countries in 2011

linkage distance	Obj. No. 1	Obj. No. 2	Obj. No. 3	Obj. No. 4	Obj. No. 5	Obj. No. 6	Obj. No. 7	Obj. No. 8	Obj. No. 9	Obj. No. 10
Amalgamation Schedule (according to selected indexes in 2011) Ward´s method, Euclidean distances										
3,961928	Bulgaria	Romania								
4,005681	Austria	Belgium								
4,463004	Germany	United Kingdom								
4,639822	Latvia	Slovakia								
4,956195	Denmark	Finland								
4,997036	Cyprus	Estonia								
6,221481	Czech Republic	Hungary								
6,224187	Denmark	Finland	Netherlands							
6,892074	Portugal	Slovenia								
7,058955	Cyprus	Estonia	Spain							
8,316957	Croatia	Latvia	Slovakia							
8,670199	Denmark	Finland	Netherlands	Sweden						
9,172015	Poland	Portugal	Slovenia							
10,63279	Croatia	Latvia	Slovakia	Italy						
10,74249	Bulgaria	Romania	Greece							
11,05718	Ireland	Luxembourg								
11,21139	Austria	Belgium	France							
12,19857	Czech Republic	Hungary	Lithuania							
13,35094	Germany	United Kingdom	Ireland	Luxembourg						
15,45812	Bulgaria	Romania	Greece	Croatia	Latvia	Slovakia	Italy			
18,81572	Austria	Belgium	France	Germany	United Kingdom	Ireland	Luxembourg			
22,20616	Cyprus	Estonia	Spain	Poland	Portugal	Slovenia				
32,33093	Bulgaria	Romania	Greece	Croatia	Latvia	Slovakia	Italy	Czech Republic	Hungary	Lithuania
57,58856	Austria	Belgium	France	Germany	United Kingdom	Ireland	Luxembourg	Denmark	Finland	Netherlands
69,79552	Cyprus	Estonia	Spain	Poland	Portugal	Slovenia	Malta			

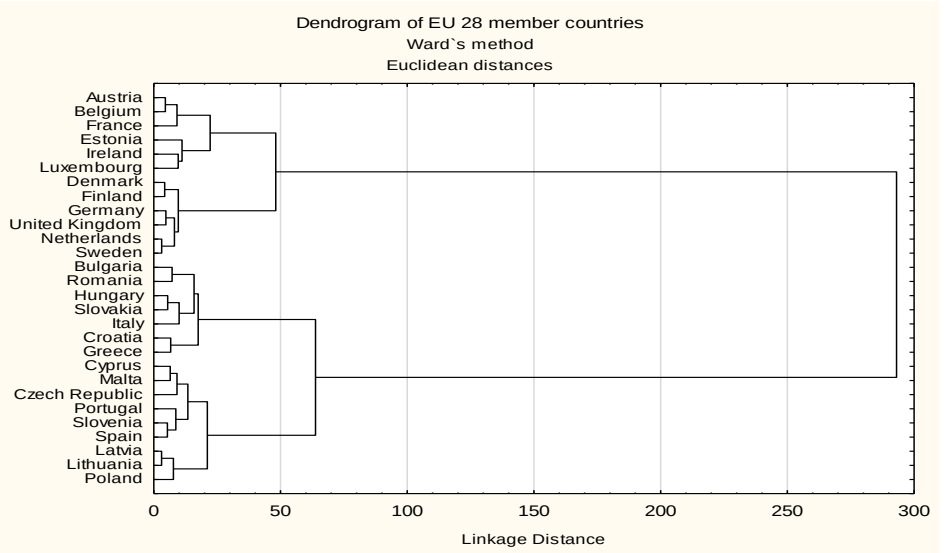
Source: own processing in STATISTICA

Based on the resulting index scores, the two economically closest countries out of the 30 analysed were Bulgaria and Romania, as the ED between them was at its lowest (3.96). In terms of index ratings, the following pairs of countries were most similar: Austria and Belgium (ED at level 4.01), Germany and United Kingdom (ED at level 4.46), Denmark and Finland (ED at level) 4.96), Cyprus and Estonia (ED at level 5.00), and the Czech Republic and Hungary (at level 6.22). On the other hand, in line with the evaluation of the individual indices, the countries reaching the most different scores were Greece and Sweden, as the ED value was the highest of all the countries (70.8). In addition to the countries mentioned above, the countries with the most distinct score were Denmark and Greece (ED at 70.4), Finland and Greece (ED at 70.42), Bulgaria, and Sweden (ED at 69.21), and Romania and Sweden (ED at 67.44). Looking at the matrix we can determine which countries are similar to each other and which, in turn, show the greatest differences. These results thus enable us not only to compare the degree of the economic prosperity of any given country, to create clusters of the most similar countries but above all to assist by targeted development of the most accurate economic development strategies for a particular country (in our case clusters) of EU countries to remove existing economic, innovative or social disparities.

Categorization of EU member states by cluster analysis in 2018

Following the above analysis, the following section also focuses on the categorization of the EU member states using cluster analysis, in which case the starting period was 2018. Even in this case, it was necessary to confirm the non-correlation of the input data. Among the selected indices, the correlation at 0.49 was confirmed, suggesting that it is appropriate to apply cluster analysis to the selected data. The following Figure 5 is presented in the form of a dendrogram for the year 2018.

Figure 5. Dendrogram of EU member countries in 2018



Source: own processing in STATISTICA

The above-mentioned dendrogram (Tree Diagram) shows the sequence of the individual EU countries' mutual connection into certain clusters based on their indices showing similar characteristics. Again, the greater the interconnectedness of the countries expressed by the value on the X-axis, the less the country is similar to the cluster formed as first. The values on the X-axis help to determine the number of clusters based on the distance of the connection of a country to a cluster. Based on Figure 6, four clusters can be identified in 2018, namely:

a) **Cluster 1**: ***"Economic leaders"*** – including six countries like Sweden, the Netherlands, the United Kingdom, Germany, Finland, and Denmark. This country cluster is characterized by the fact that the score of all the indices reached the highest value (average maximum). Thus, the observed results reveal that in the analysed economic spheres of the countries (according to the indices), they belonged among the EU leaders. This cluster of countries recorded a significantly higher score than was the EU average for the CPI and the GII. On the contrary, the lowest deviations of this group of countries were observed in the HDI index. It is common knowledge that the Nordic countries, together with the United Kingdom and Germany, are among the most advanced countries in Europe, with a highly developed level of social, innovation or economic conditions, as confirmed by the results of the analysis. Economic activity, innovative development, entrepreneurial prosperity, as well as the social dimension – in all of the areas, these countries obtained high scores, as evidenced by the ratings of the analysed countries.

b) **Cluster 2**: "***Economically advanced countries***" – including six countries like Luxembourg, Ireland, Estonia, France, Belgium, and Austria. Neither any average index minimums nor maximums were identified within this country cluster. Nonetheless, it

is this cluster that obtained 2nd highest average score (the 1st belongs to Cluster 2) when assessed by all the indices. The average indices values in the selected country cluster received a significantly higher score than the EU average. When compared to the EU average for 2018, the countries included in this cluster showed the most significant difference in the CPI index, as the index of this group of countries exceeded the EU average by 15.96%. However, the identified differences of all the other indices were not of significance, with the lowest difference at 2.60% being quantified for the HDI index. As for 2018, it can be concluded that while the countries enjoyed satisfactory economic prosperity, they showed some limits that prevented them from being the best EU countries from the economic point of view.

c) **Cluster 3**: ***"Economically average countries"*** – including nine countries like Poland, Lithuania, Latvia, Spain, Slovenia, Portugal, the Czech Republic, Malta, and Cyprus. The following cluster (similarly to Cluster 1) did not show any average minimums or maximums in any of the indices, achieving the 2nd lowest average score within the monitored indices. The Cluster 4 average score indicates that these countries reached a score roughly equal to the EU average. Average score values were below the EU average, ranging from 1.69% (for EFI) to 8.78% (for CPI). Based on the resulting index score for 2018, it can be stated that countries belonging to this cluster were among the EU average in assessing economic maturity. Yet it is necessary to point out that while these countries have lagged behind the most advanced EU countries, their limits did not belong to the worst among EU countries.

d) **Cluster 4**: "***Economically limited countries***" – including seven countries like Greece, Croatia, Italy, Slovakia, Hungary, Romania, and Bulgaria. This group of countries can be described as the least economically efficient, as the countries belonging to this Cluster acquired average minimum when evaluated by all the indices. These countries are characterized by the fact that they were lagging behind the EU average in 2018 by 13.17% on average. Based on the analysis of the individual indices and their average value, it was shown that the largest issues of these countries were related to corruption, as the CPI lagged behind the EU average the most together with GII innovations. In contrast, the HDI human development domain was at its best. According to the 2018 index, these 7 countries were among the weakest in the EU countries, with many limits in economic development.

In the next section, we focused on creating the Distance matrix and the Amalgamation table (Figure 6). It was not possible to present the entire table because it contains 30 rows and 30 columns. For that reason, we present only a part of the Amalgamation table below.

Based on the results shown in the Distance matrix and the Amalgamation schedule for 2018, we found out several facts. According to the overall index scores, Latvia and Lithuania were among the two most economically similar countries within the European grouping of countries, since the ED recorded the lowest value at 3.01. Besides this compared couple of countries, the following ones indicated similarity – the Netherlands and Sweden (ED at level 3.13), Denmark and Finland (ED at level 4.31), Austria and Belgium (ED at level 4.57), Germany and the United Kingdom (ED at level 4.76), Slovenia and Spain (ED at level 5.38), Hungary and Slovakia (ED at level 6.48), Croatia and Greece (ED at level 6.68), and Bulgaria and Romania (ED at 7.24). A different

example of the assessment is the couple comprised of Denmark and Greece, which reached the highest ED within the analysed EU countries at 54.65, meaning that according to all the indices, the two countries are the least similar. Among the most distinct countries belonged the following pairs: Sweden and Greece (ED at 54.45), Bulgaria and Denmark (ED at level 53.72), the Netherlands and Greece (ED at 52.67), and Croatia and Denmark (ED at 51.81). With the help of specified distances in the matrix, it is thus possible to identify the least closely related countries (with the most distinctive degree of economic prosperity), but also the countries the most similar to the ratings chosen by the indices.

Figure 6. Amalgamation schedule of EU member countries in 2018

Amalgamation Schedule (according to selected indexes in 2018)
Ward's method; Euclidean distances

Linkage distance	Obj. No. 1	Obj. No. 2	Obj. No. 3	Obj. No. 4	Obj. No. 5	Obj. No. 6	Obj. No. 7	Obj. No. 8	Obj. No. 9	Obj. No. 10
3,083829	Latvia	Lithuania								
3,126647	Netherlands	Sweden								
4,310831	Denmark	Finland								
4,574976	Austria	Belgium								
4,756886	Germany	United Kingdom								
5,383307	Slovenia	Spain								
5,481956	Hungary	Slovakia								
6,488263	Cyprus	Malta								
6,677422	Croatia	Greece								
7,240589	Bulgaria	Romania								
7,760688	Latvia	Lithuania	Poland							
8,126153	Germany	United Kingdom	Netherlands	Sweden						
8,681858	Portugal	Slovenia	Spain							
9,160064	Cyprus	Malta	Czech Republic							
9,178613	Austria	Belgium	France							
9,634060	Ireland	Luxembourg								
9,681099	Denmark	Finland	Germany	United Kingdom	Netherlands	Sweden				
9,985124	Hungary	Slovakia	Italy							
11,14322	Estonia	Ireland	Luxembourg							
13,46337	Cyprus	Malta	Czech Republic	Portugal	Slovenia	Spain				
15,90192	Bulgaria	Romania	Hungary	Slovakia	Italy					
17,51478	Bulgaria	Romania	Hungary	Slovakia	Italy	Croatia	Greece			
21,11529	Cyprus	Malta	Czech Republic	Portugal	Slovenia	Spain	Latvia	Lithuania	Poland	
22,24063	Austria	Belgium	France	Estonia	Ireland	Luxembourg				
48,14764	Austria	Belgium	France	Estonia	Ireland	Luxembourg	Denmark	Finland	Germany	United Kingdom
63,81261	Bulgaria	Romania	Hungary	Slovakia	Italy	Croatia	Greece	Cyprus	Malta	Czech Republic

Source: own processing in STATISTICA

Based on the above results, we conclude that EDs between European countries are significantly lower in 2018 compared to 2011. Thus, these results indicate a reduction in the economic disparities of individual countries, which is a sign of a successful EU direction on the path of building an economically, socially, but also an innovatively united and balanced political-economic grouping of countries. This suggests that a country development strategy has been successfully designed and implemented over the last 8 years, and disparities between EU economies have been successfully eliminated over time.

Based on the analysis of the EU member states using selected international indices for 2011 and 2018, we reached the following conclusions. The rate of change (improvement) of the EU member states was quantified at level 21.43%. We can state, that major part of the EU member states clusters into the same groups based on the selected indices assessment, regardless of the time period. Only 6 countries (the Czech Republic, Esto-

nia, Germany, Latvia, Lithuania, and the United Kingdom) were exceptions, all of which improved their position during the period under review and ranked among the cluster of more prosperous EU countries in 2018. The overall comparison of cluster membership of countries is presented in Table 1 below.

Table 1. The cluster membership comparison of EU member states

Country	Cluster membership		Country	Cluster membership	
	2011	2018		2011	2018
Austria	2	2	Italy	4	4
Belgium	2	2	Latvia	4	3
Bulgaria	4	4	Lithuania	4	3
Croatia	4	4	Luxembourg	2	2
Cyprus	3	3	Malta	3	3
Czech Republic	4	3	Netherlands	1	1
Denmark	1	1	Poland	3	3
Estonia	3	2	Portugal	3	3
Finland	1	1	Romania	4	4
France	2	2	Slovakia	4	4
Germany	2	1	Slovenia	3	3
Greece	4	4	Spain	3	3
Hungary	4	4	Sweden	1	1
Ireland	2	2	United Kingdom	2	1

Source: own processing.

In the context of the selected indices scores within the EU member states and by the implemented cluster analysis, the following order of clusters (from the best to the worst results) can be created:

$$1^{st}\ \text{Cluster} \Rightarrow 2^{nd}\ \text{Cluster} \Rightarrow 3^{rd}\ \text{Cluster} \Rightarrow 4^{th}\ \text{Cluster}$$

Cluster analysis allows us to answer the question, which country is "typical and the most average", i.e., the closest to all the others (or "atypical") according to the monitored indices, which represent the level of economic prosperity in the various assessment areas. Taking into account the score of all the indices for 2011, Spain was identified as the most average EU country. In contrast, Malta achieved the most different index scores from the average. We also did the same analysis for 2018, where Slovenia received the most average results from the EU in that year, while Greece was the most deviating from the EU average.

Finally, the attention was focused on analysing economic connections. Most of the countries were integrated into clusters in accordance with expectations. However, in the case of certain countries, unexpected cluster membership was shown. For example, Germany was included into the "Economically advanced countries" in 2011, not into the "Economic leaders" of the EU. This is probably the results of the economic debt crisis in 2008. In 2018, as compared to 2011, the economic situation had improved globally, and Germany was grouped among the "Economic leaders".

Furthermore, in the case of Italy, a surprising finding was obtained, as this country was included among "Economically limited countries" (the worst-performed). According to

economists, Italy's public debt at around 132% of GDP is the second-highest in the Eurozone and has remained constant since 2010. It is good that it is not rising. On the other hand, the problem is that it is not falling. Moreover, Italy does not achieve GDP growth.

Conclusion and discussion

The main aim of the paper was to evaluate the economic and social development of EU member states on the basis of international indices (GCI, EFI, GII, CPI, and HDI). In order to fulfill settled aim, a multidimensional classification of EU countries (based on similar or different characteristics) for the years of 2011 and 2018 by application of cluster analysis was performed. The purpose of the analysis was to categorize individual EU countries into clusters and to find out to what extent the position of the EU Member States has changed in terms of the selected international indices over the analysed period. We decided to carry out this research using up to five multicriteria indices, which include several other important aspects and criteria that significantly affect the economic growth and social aspects of countries. They were selected to encompass the economic, social, demographic, technological, cultural, and quality of life conditions. Therefore, this research combines traditional economic, technological, and sociocultural variables with a variety of quality-of-life type indices that have recently become available. The added value of the paper lies in furthering the research to find out how, besides hierarchy, EU member states can be analysed from the point of view of various multicriteria indices.

The analysis of EU member states for 2011 revealed that some countries achieved double representation in the ranking of selected indices. As examples, the ranking position of Denmark, Bulgaria, Greece, and Sweden. According to the results of the Distance matrix and the Amalgamation schedule for 2011, we can state that Bulgaria and Romania (ED 3.96) were indicated as the most economically similar countries, while Greece and Sweden were the most different ones (ED 70.8).

Based on the analysis for 2018, we identified the countries again that dominated the rankings of two indices at the same time. As examples, the ranking position of Germany and Bulgaria. According to the results of the Distance matrix and the Amalgamation schedule for 2018, we can state that Latvia and Lithuania were indicated as the most similar countries (ED 3.01), while Denmark and Greece were the most different (ED 54.65) in terms of various economic prosperity areas.

Finally, we can conclude that cluster analysis revealed the rate of change of the EU member states quantified at level 21.43%, i.e., that the 22 economies of the EU member states, as assessed by selected indices, were categorized into the same clusters regardless the time period and six countries (the Czech Republic, Estonia, Germany, Latvia, Lithuania, and the United Kingdom) achieved better overall assessment. In the case of these six countries, positive development was quantified. Consequently, all the abovementioned countries were integrated into a better cluster. Increasing competitiveness and decreasing corruption belonged to the most significant factors determining the countries positions improvement.

The issues of efficiency and performance, growth, as well as an understanding of the market, the competitive features, and success factors to help better define a sustainable value proposition is examined in all economic areas (Stefko et al., 2017; Stefko and Steffek, 2017). The growing international competitiveness, dynamic development of information and communications technology, the growing role of knowledge, demographic problems, and shortage of resources created great EU challenges (Stec and Grzebyk, 2018; Gallo et al., 2019). The above-mentioned circumstances have increased competition and forced all the economies to pay more attention to competitiveness assessment and sustainable economic development. Today's Europe seeks smart, inclusive, and environmentally-conscious economic growth. This fact is also highlighted by Dobrovic et al. (2018), who consider the EU growth as the combination of intelligent and sustainable growth and growth-supporting integration. Moreover, one of the most urgent economic issues is, according to Onyusheva (2017), the formation of a high level of competitive human capital.

All above-mentioned aspects are considered key determinants in the process of sustainable economic development. The findings of this study (based on the decreasing values of EDs) confirmed that the economic disparities of the EU member states are eliminated gradually in the period under review. In accordance with the results, it is possible to assert that the EU has successfully implemented economic, social, innovative, and business strategies to build a united and balanced community.

In our opinion, the competitiveness of the EU has improved, and moreover, individual countries are able to implement target strategies to build a competitive and united union. Despite these positive findings, the study also identified problematic economic areas of each EU member states. In this regard, we recommend the countries included in 4th cluster (economically limited countries) to focus on solving problems related to economic development (competitiveness, economic freedom, innovation, corruption, and human development). Furthermore, the presented study can help all the EU Member States identify their social and economic development level. Finally, it is necessary to emphasize that research findings can be useful for national governments of individual EU countries in suggesting and implementing particular economic strategies translated into action plans according to the country membership in a given cluster.

In conclusion, it is necessary to state that research findings are also subjected to some limitations. Despite the fact that research was focused on the EU member states, the validity of this paper for individual countries is debatable. Another limitation can be found in the application of presented findings in practice, as individual EU countries are confronted with different economic, political, and social problems. The research results may also be perceived as relatively general from the point of view of policymakers. For this reason, the deeper analysis of countries within clusters is recommended for the future. The creation of cluster profiles can help to interpret and compare the basic characteristics of the individual clusters, yet it is required to analyse not only the overall score of indices but also particular pillars or indicators. Our further research might focus on the detection of factors improving or decreasing the countries positions within the selected global multicriteria indices. Furthermore, it is necessary to mention that the result of the cluster analysis depends on the researcher's attitude to the selection of indices, method of the clustering, and the time period, so findings are significantly limited. In order to obtain meaningful results, such a-theoretical approach often needs to be

combined with prior hypotheses about the importance of some clustering criteria based on the researcher's experience.

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