

# Application of multivariate statistical analysis to assess the implementation of Sustainable Development Goal 8 in European Union countries<sup>1</sup>

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**Abstract.** Sustainable development should ensure a fair and balanced natural, social and economic environment. Sustainable Development Goal 8 (SDG 8) – decent work and economic growth – is of the greatest economic importance. The purpose of the study is to assess the implementation of SDG 8 in EU member states. The analysis covered the years 2002–2021 with a particular focus on two crises periods: the financial crisis of 2007–2009 and the COVID-19 pandemic in the years 2020–2021. The study uses Eurostat data and multivariate statistical analysis methods, i.e. cluster analysis – the *k*-means method and linear ordering – the TOPSIS method.

Denmark, Finland, the Netherlands and Sweden are the countries where the fulfilment of SDG 8 was the greatest, while the lowest was observed in Greece, Italy, Romania, Slovakia and Spain. The study also shows that the countries which joined the EU in 2004 generally demonstrated a much lower degree of SDG 8 implementation compared to the well-developed Western Europe. The influence of the crisis periods was more visible in the results of the cluster analysis than in the rankings.

The novelty of the research involves the application of multivariate statistical analysis methods to assess the overall situation of the studied countries in terms of their implementation of SDG 8 while taking into account both crisis periods.

**Keywords:** sustainable development, Sustainable Development Goal 8, decent work and economic growth, EU member states, TOPSIS method, *k*-means method

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# Zastosowanie wielowymiarowej analizy statystycznej do oceny realizacji Celu Zrównoważonego Rozwoju 8 w krajach Unii Europejskiej

**Streszczenie.** Zrównoważony rozwój powinien zapewnić sprawiedliwe i zrównoważone środowisko naturalne, społeczne i gospodarcze. Godna praca i wzrost gospodarczy, czyli Cel Zrównoważonego Rozwoju (Sustainable Development Goal – SDG) 8, ma największe znaczenie gospodarcze. Celem badania omawianego w artykule jest ocena realizacji SDG 8 w krajach członkowskich UE. Badanie obejmowało lata 2002–2021, ze szczególnym uwzględnieniem okresów kryzysowych: kryzysu finansowego z lat 2007–2009 i pandemii COVID-19 panującej w latach 2020–2021. W badaniu wykorzystano dane z bazy Eurostatu. Zastosowano metody wielowymiarowej analizy statystycznej: analizę skupień metodą  $k$ -średnich i porządkowanie liniowe metodą TOPSIS.

Krajami o najwyższym stopniu realizacji SDG 8 okazały się: Dania, Finlandia, Holandia i Szwecja, natomiast najniższy stopień realizacji obserwowano w Grecji, we Włoszech, w Rumunii, na Słowacji i w Hiszpanii. Również nowe kraje członkowskie, przyjęte do UE po 2004 r., ogólnie charakteryzują się znacznie niższym stopniem realizacji SDG 8 niż wysoko rozwinięte kraje Europy Zachodniej. Wpływ okresów kryzysowych był bardziej zauważalny w wynikach analizy skupień niż w rankingach.

Wartością dodaną badania jest wykorzystanie metod wielowymiarowej analizy statystycznej do oceny ogólnej sytuacji analizowanych krajów w zakresie realizacji SDG 8 przy uwzględnieniu obu okresów kryzysowych.

**Słowa kluczowe:** zrównoważony rozwój, Cel Zrównoważonego Rozwoju 8, godna praca i wzrost gospodarczy, kraje członkowskie UE, metoda TOPSIS, metoda  $k$ -średnich

## 1. Introduction

Sustainable development assumes the parallel development of the economy, society and the environment. Many legal acts, political documents, development strategies at all levels of aggregation, from local to global, refer to this concept. Its implementation tends to be difficult as it is of a complex and interdisciplinary character. Sustainable development has been defined as one which meets the needs of people in the present without compromising the ability of future generations to fulfil their needs. The achievement of sustainable development goals (SDGs) depends on many factors. As research by Zioło et al. (2021) indicates, there is a strong link between economic sustainability reflected in e.g. Sustainable Development Goal 8 (SDG 8) and the sustainable finance model. SDG 8 relates to well-being and quality of life and is impossible to attain through a sustainable public financial system alone. It also requires the cooperation with and involvement of a sustainable market financial system. Sustainable development requires a common effort to build a sustainable and crisis-resilient future for people around the world and for the planet.

Crises which may interfere with the assumed goals can be of an economic (linked to banking, currency, stock market, finances or overproduction), ecological, political (e.g. war) or demographical (associated with migrations, decrease of fertility, etc.) nature as well as health-related (e.g. pandemics). The spread of their effects is influenced by any existing links between markets, systemic risks or faulty regulations (Roszkowska & Prorokowski, 2014). In the last 20 years, the world faced two crises: the financial one of 2007–2009 and the COVID-19 pandemic, which emerged in early 2020 and whose consequences ensued in the years that followed. Both phenomena had a great impact on the socio-economic development of countries around the world due to their numerous and strong economic interconnections.

The impact of crises on individual economies tends to vary across countries and is visible both in its first phase, i.e. during the emergence of its negative effects, and in the post-crisis economic growth (Foo & Witkowska, 2017). Crises have been analysed and researched by many scientists worldwide (Clemente-Suárez et al., 2021; Sombultawee et al., 2022). It has been found that if a key sector of the economy collapses during a crisis, the economic equilibrium of the entire country is disrupted. For example, during the COVID-19 pandemic movement restrictions were introduced which particularly affected transport and tourism. Hence, countries with GDPs heavily dependent on these and the related industries were greatly affected by the pandemic (Ružić & Popek Biškupec, 2021; Škare et al., 2020). Some sectors, however, attempted to adapt to the new conditions: remote working and learning became widespread, remote concerts took place and even online visits to museums were possible (Domšić et al., 2021). Despite the measures taken, poverty and unemployment rates increased (Jianu et al., 2021). Economic and social development was particularly severely disrupted. Therefore, there is no doubt that crises of all kinds, especially those of a global nature, pose a threat to the achievement of SDGs. Preliminary research on the EU labour market (SDG 8.5, SDG 8.6) from the years 2018–2021 showed that the COVID-19 pandemic did not affect the similarities of the labour markets in the EU countries, but rather influenced the similarities of changes in those markets (Bieszk-Stolorz & Dmytrów, 2022).

The purpose of the study is to assess the implementation of SDG 8 in EU countries. The analysis covered the years 2002–2021 with a particular focus on the crisis periods: the financial crisis (2007–2009) and the COVID-19 pandemic (2020–2021).

## 2. Sustainable Development Goals

SDGs were established during the United Nations General Assembly in 2015 (Resolution adopted by the General Assembly on 25th September 2015). SDG 8 is to ‘promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all. SDG 8 is the aspiration that the economic sector of each country should provide its citizens with the necessary needs for a good life, regardless of their origin, race or culture’. SDG 8 has a total of 12 targets, presented in Table 1.

**Table 1.** SDG 8 targets

Target no.	Description
8.1 .....	sustainable economic growth
8.2 .....	to diversify, innovate and upgrade for economic productivity
8.3 .....	to promote policies to support job creation and growing enterprises
8.4 .....	to improve resource efficiency in consumption and production
8.5 .....	full employment and decent work with equal pay
8.6 .....	to promote youth employment, education and training
8.7 .....	to end modern slavery, trafficking, and child labour
8.8 .....	to protect labour rights and promote safe working environments
8.9 .....	to promote beneficial and sustainable tourism
8.10 .....	universal access to banking, insurance and financial services
8.a .....	to increase aid for trade support
8.b .....	to develop a global youth employment strategy

Source: authors’ work based on United Nations (n.d.).

The progress towards achieving the 17 goals is measured, monitored and evaluated by means of different sets of indicators, used at different levels of sustainable development monitoring. The UN applies a global set of indicators, while Eurostat provides a set of indicators for the EU. In addition, each country monitors its own priorities with a different set of indicators, tailored to the specifics of the country or region.

The Sustainable Development Goals Report 2021 (United Nations, 2021) indicates that even before the pandemic began, global economic growth had already faced a slowdown. However, the outbreak of the pandemic in 2020 severely disrupted economic activity around the world. The recession that resulted from COVID-19 was considered the worst since the Great Depression. The above-mentioned report concluded the following with regard to the SDG 8 targets:

1. For many countries, the road to economic recovery may be long and bumpy.
2. COVID-19 has led to massive job losses, particularly among young people and among women.

3. The lack of a social safety net has left informal workers on their own to cope with the COVID-19 fallout.
4. The worst year on record for international tourism disproportionately affected small-island, developing states.
5. The pandemic has led to an increase in the number of young people who are not employed, in school or in training.

### 3. Literature review

The implementation of SDGs is not an easy task. Modern economics must be re-oriented from the direction of economic growth to the direction of sustainable development. In many countries, along with Poland, mainstream economics did not include the concept of sustainable development as the main theory of management and a foundation for a rational policy (Kostka, 2011). In the years 2010–2015, the ‘Europe 2020’ strategy prevailed as one ensuring social equality. The analysis of the key indicators of social equality outlined in this strategy showed a large diversity in inequality patterns, as both an increase and decrease in inequality at the EU level were observed. These changes are most often related to the business cycle, especially to labour market access and income inequality (Stanickova, 2017).

Many studies stress that the leading EU economies are not only the drivers of development within the EU, but also in other, non-EU countries. For example, research by Radulović and Kostić (2021) shows a significant long-term relationship between the real GDP of Germany and France and that of Serbia. Moreover, in the case of France, it has a short-term positive impact on the Serbian economy. In contrast, no short-term impact of the German economy is observed here.

As regards Poland, the last decade was characterised by positive changes in the area of sustainable development. However, the scale of these changes was smaller than the EU average. The COVID-19 pandemic in Poland caused a short-lived, yet pronounced decline in macroeconomic performance and may have also affected the scale of the economy’s impact on the environment (Główny Urząd Statystyczny [GUS], 2022).

Pełka (2019) conducted a development analysis for 30 European OECD countries. The analysis involved linear ordering and cluster analysis based on a symbolic-numeric approach for linear ordering visualisation, and single and ensemble clustering for symbolic interval-valued data. Two clusters of countries were obtained. Cluster 1 included the most developed countries: Denmark, Finland, France, Germany, Iceland, Italy, Norway, Sweden, and the United Kingdom, and a pattern object. The objects from this cluster were most similar to one another. Cluster 2 included the following countries: Austria, Belgium, Bulgaria, Croatia,

Cyprus, Czechia, Estonia, Greece, Hungary, Ireland, Latvia, Lithuania, Luxembourg, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Switzerland, and an anti-pattern object. These were highly and medium-highly developed states. The countries in this cluster were the least similar to each other.

A number of studies related to sustainable development are being undertaken, among which circular economy (CE) development is particularly promoted (Skvarciany et al., 2021). In Europe, Scandinavian countries recorded the highest level of CE in 2019, while Greece, Luxembourg and Poland the lowest. Similar conclusions were reached by Zioło et al. (2019). Their study indicates that in the case of Scandinavian countries, economic growth does not entail neglecting environmental issues, while the opposite is observed in economically less developed countries (Greece, Hungary, Poland and Portugal). The classification of EU countries by Piwowarski et al. (2018) based on two methods: TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) and VIKOR (VIseKriterijumska Optimizacija I Kompromisno Resenje) showed that in 2016, Austria was the most sustainable country and Romania was the least. The weak position of Romania as well as Bulgaria was also confirmed by the study of Stanujkic et al. (2020). Both countries are located in Eastern Europe and joined the EU in 2007. They have not yet properly incorporated sustainability as a postulate in their policies.

This study uses the multiple-criteria decision-making approach (MCDM) in defining the position of the EU countries relative to SDGs in the years 2015–2018. The analysis indicated that Sweden was the leader in SDG implementation. Observation of the input data for this country showed, however, that its achievements were not the best in all segments. However, Sweden's attainments outlined in Agenda 2030 were always between average and the best, placing Sweden as the country that made the most significant progress towards SDGs during the period of 2015–2018.

Rocchi et al. (2022) presented the evolution of an existing sustainability index in order to measure the progress of EU countries towards the achievement of the objectives of Agenda 2030. They proposed the Sustainable Development Goals Achievement Index (SDG-AI), which represents all the sustainability-related information. The study showed that in 2019, in terms of SDG-AI among EU countries, the Nordic countries (Denmark, Finland and Sweden) were the most advanced. They were at the top of the ranking in all the verified dimensions, except for the environmental one in the case of Denmark. In contrast, the EU Baltic States and the former Eastern Bloc countries achieved the lowest scores. Good governance and institutional effectiveness are associated with long-run development and sustainability success (Barbier & Burgess, 2021), which explains the high position of the Nordic countries in the context of SDGs implementation. On the other hand, the

low position of the EU post-communist countries results from their later accession to the EU. It should be noted, however, that it had a positive impact on their economic development, including their labour markets (Bieszk-Stolorz & Dmytrów, 2020; Dmytrów & Bieszk-Stolorz, 2021).

#### 4. Research method

The achievement of SDG 8 is monitored by means of indicators. The global set of SDG 8 indicators defined by the UN consists of 16 of them (GUS, n.d. a), while the example set of indicators for Poland contains 13 (GUS, n.d. b). This research is based on the set of indicators provided by Eurostat for the needs of EU countries.

The empirical analysis involves two steps. In the first step, we assess the degree to which particular countries achieved SDG 8 through the composite measure based on the TOPSIS method. It is then used to create the rankings of countries. In the second step, we divide the EU countries into homogeneous clusters using the  $k$ -means method. The research period covers the years 2002–2021. The first year is 2002, with data available for at least half of the variables (indicators). All data come from Eurostat and refer to the variables that describe the targets specified in SDG 8. There are eight variables that we take into consideration (square brackets represent the codes for the variables in the Eurostat database):

- $x_1$  – GDP *per capita* in constant prices from the year 2021 (in euro, available for the whole period) [SDG\_08\_10],
- $x_2$  – investment share of GDP by institutional sectors (percentage of GDP, available for the whole period) [SDG\_08\_11],
- $x_3$  – young people (aged 15–29) not in employment, nor in education or training, by sex (NEET) (percentage of the total population, available for the whole period) [SDG\_08\_20],
- $x_4$  – employment rate (for persons aged 20–64) (percentage of the total population, available for the whole period) [SDG\_08\_30],
- $x_5$  – long-term unemployment rate (percentage of the total population in the labour force, available for the period of 2009–2021) [SDG\_08\_40],
- $x_6$  – in work at-risk-of-poverty rate (percentage of the total employed persons, aged 18 and more, available for the period of 2005–2021) [SDG\_01\_41],
- $x_7$  – fatal accidents at work per 100,000 workers (available for the period of 2010–2019) [SDG\_08\_60],
- $x_8$  – inactive population due to caring responsibilities (percentage of population aged 20–64, outside the labour force and wanting to work, available for the whole period) [SDG\_05\_40].

Variables  $x_1$ ,  $x_2$  and  $x_4$  are stimulants (variables, for which the highest values are the most desirable), while the remaining ones are destimulants (variables, for which the lowest values are the most desirable). We perform calculations in the years 2002–2004 for four variables, in the years 2005–2008 for six variables, in the years 2009 and 2020–2021 for seven variables and in the years 2010–2019 for all eight variables. The different number and different sets of variables in each year depended on their availability. The European countries were not in all cases obliged to provide specific data in their reports (due to the different periods of their accession to the EU). Variables were analysed with respect to their variability. Most of them were characterised by at least a 15% of coefficient of variation. Only one variable –  $x_4$  (employment rate) – had the level of variability slightly lower than 10%. However, if it was excluded from the analysis, the results were exactly the same. Nevertheless, as the employment rate is a very important variable with respect to EU policy, the decision was to leave it in the set of variables.

We perform the calculations in Microsoft Excel for Microsoft 365 and in R language (R Core Team, 2022) with the use of two libraries: `clusterSim` (Walesiak & Dudek, 2020) and `factoextra` (Kassambara & Mundt, 2020).

#### 4.1. The TOPSIS method

There are many techniques of performing the linear ordering of objects. On the basis of multivariate statistical analysis, one of the first proposals of constructing the composite measure was the composite measure of development, proposed by Hellwig (1969, 1972a, 1972b). TOPSIS is a multivariate technique created for the need of multi-criteria decision-making. It is, however, also widely used in multivariate statistical analysis. It is one of the methods of the linear ordering of objects. It was devised by Hwang and Yoon (1981). Its idea is based on the weighted distance of each object (in our case each EU country) from the best values in the dataset (the pattern) and the worst ones (the anti-pattern). The starting point of every multivariate statistical method is observation matrix  $\mathbf{X}$ :

$$\mathbf{X} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix}, \quad (1)$$

where:

$x_{ij}$  – value of the  $j$ -th variable in the  $i$ -th object ( $i = 1, \dots, n$ ,  $j = 1, \dots, m$ ),

$m$  – number of variables,

$n$  – number of objects.



As the variables are in most cases measured in different units, the first step to the further analysis is the normalisation of data. We use one of the quotient inversions:

$$z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^n x_{ij}^2}}, \quad (2)$$

where  $z_{ij}$  – normalised value of the  $j$ -th variable in the  $i$ -th object ( $i = 1, \dots, n$ ,  $j = 1, \dots, m$ ).

The main reasons for using this method were as follows: it did not change the measurement scale of the variables, the normalised variables differed with respect to the level of the central tendency and variability, and it was the method that the authors had applied when they had proposed the TOPSIS method.

In the next step, we apply weights to the variables, which is not an easy task. It is difficult to discern which variables are more important than others. There are various methods of assigning weights to the variables: the naïve method (assuming equal weights), methods based on the variables' variation, correlation coefficients, Shannon's entropy, ranks and expert methods. As the set of variables is different in various years, we use the naïve method and assume equal weights imposed on variables. The weight of every variable  $w_j$  equals  $\frac{1}{m}$  and the condition  $\sum_{j=1}^m w_j = 1$  is satisfied. After the weighing, we obtain a weighed, normalised observation matrix:

$$t_{ij} = w_j z_{ij}, \quad i = 1, \dots, n, \quad j = 1, \dots, m. \quad (3)$$

On the basis of the weighed observation matrix for every variable, we find the pattern (the best value in the dataset, denoted by  $A_b$ ) and anti-pattern (the worst value in the dataset, denoted by  $A_w$ ):

$$A_b = \left\{ \left( \max_i t_{ij} | j \in J^+ \right), \left( \min_i t_{ij} | j \in J^- \right) | i = 1, \dots, n \right\} = \{t_{b1}, \dots, t_{bj}, \dots, t_{bm}\}, \quad (4)$$

$$A_w = \left\{ \left( \min_i t_{ij} | j \in J^+ \right), \left( \max_i t_{ij} | j \in J^- \right) | i = 1, \dots, n \right\} = \{t_{w1}, \dots, t_{wj}, \dots, t_{wm}\}, \quad (5)$$

where:

$J^+$  – stimulants,

$J^-$  – destimulants.

In the subsequent step, we calculate the weighted distance of every object from the pattern ( $d_{i0}^+$ ) and anti-pattern ( $d_{i0}^-$ ). The most popular distance measure is the Euclidean measure, which we also use as follows:

$$d_{i0}^+ = \sqrt{\sum_{j=1}^m (t_{ij} - t_{bj})^2}, \quad i = 1, \dots, n, \quad (6)$$

$$d_{i0}^- = \sqrt{\sum_{j=1}^m (t_{ij} - t_{wj})^2}, \quad i = 1, \dots, n. \quad (7)$$

The composite measure in the TOPSIS method is calculated by means of the following equation:

$$q_i = \frac{d_{i0}^-}{d_{i0}^- + d_{i0}^+}, \quad i = 1, \dots, n. \quad (8)$$

Measure  $q_i$  is normalised – it belongs to interval  $[0, 1]$ . The best object has the highest value of  $q_i$  and the worst object the lowest.

#### 4.2. The $k$ -means method

The  $k$ -means method is a technique used in cluster analysis, proposed by MacQueen (1967). Cluster analysis aims at the separation of homogeneous groups of objects ( $P_1, \dots, P_u$ ) from the set of all objects  $\Omega = \{O_1, O_2, \dots, O_n\}$ , where  $u$  is the number of clusters, and  $n$  represents the number of objects ( $u \leq n$ ). The obtained clusters should satisfy two conditions: firstly, the objects within the cluster should be to the highest degree similar with respect to the values of the variables, and secondly, the objects in different clusters should be to the highest degree different with respect to the values of the variables. The methods in cluster analysis are divided into two groups. The first group consists of hierarchical clustering methods (agglomerative and deglomerative). The second group is formed by methods optimising the initial division of objects. The  $k$ -means method belongs to the second group (Everitt et al., 2011).

The initial steps of the  $k$ -means method (or any other cluster analysis technique) is the same as in the case of the linear ordering methods. In the first step we have the observation matrix (1), which is then normalised. We use the same normalisation method (2) as in the case of the TOPSIS technique. The distance between the objects is calculated by means of the Euclidean metric. The steps of the  $k$ -means method are as follows:

1. The division of the set of objects into  $s$  clusters ( $s = 1, \dots, k, \dots, n$ ).
2. Calculation of the centre of gravity (centroid) and the distance of every object from it for every cluster.
3. Change of the assignment of objects to clusters with the closest centroid.
4. Calculation of the new centroids.
5. Repeating steps 3–4, until the next relocation of objects will cease to improve the general distances of the objects from the centroids.
6. Repeating steps 2–5 for various numbers of clusters.

The procedure above is very time-consuming; therefore, we can apply various methods to determine the optimal number of clusters. These methods are divided into two groups: graphical and those based on quality assessment indexes. One of the most widely-used indexes is the Caliński and Harabasz index. It is calculated by means of the following equation (Everitt et al., 2011):

$$C(k) = \frac{\text{trace}(\mathbf{B})}{\frac{k-1}{n-k} \text{trace}(\mathbf{W})}, \quad (9)$$

where:

$k$  – number of clusters,

$\text{trace}(\mathbf{B})$  – trace of the between-group dispersion matrix,

$\text{trace}(\mathbf{W})$  – trace of the within-group dispersion matrix.

The optimal number of clusters is the one that maximises the value of  $C(k)$ . Having selected the number of clusters ( $k$ ), we chose the optimal division of objects between them ( $\mathbf{P}$ ) by means of the cost, measured as the sum of squares of the within-group distances from the centroids:

$$\text{Cost}_{\mathbf{P}}^* = \underset{\mathbf{P}}{\text{argmin}} \sum_{s=1}^k \sum_{z_{ij_s} \in P_s} (d_{is} - \bar{d}_s)^2, \quad (10)$$

where:

$P = \{P_1, \dots, P_k\}$  – set of homogeneous clusters,

$d_{is}$  – distance of the  $i$ -th object from the centroid for the  $s$ -th cluster,

$\bar{d}_s$  – centroid for the  $s$ -th cluster.

## 5. Empirical results

In the first step of the analysis, we perform the linear ordering of countries according to the fulfilment of SDG 8 by means of the TOPSIS method. In order to ensure the

comparability of the obtained composite measures  $q_i$ , the anti-pattern and pattern values of the variables were calculated for the whole period. They are presented in Table 2.

**Table 2.** Anti-pattern and pattern values of variables presenting the SDG 8 indicators

Specification	$x_1$	$x_2$	$x_3$	$x_4$	$x_5$	$x_6$	$x_7$	$x_8$
Anti-pattern .....	1,704.78	10.58	31.00	52.50	17.50	19.80	6.37	75.70
country .....	Romania	Greece	Bulgaria	Greece	Greece	Romania	Romania	Malta
year .....	2002	2019	2002	2013	2014	2014	2011	2004
Pattern .....	86,550.00	53.59	4.70	81.80	0.60	2.70	0.45	2.40
country .....	Luxembourg	Ireland	Denmark	Sweden	Czechia	Finland	Malta	Sweden
year .....	2021	2019	2006	2018	2019	2017	2017	2002

Note.  $x_1$  – SDG\_08\_10,  $x_2$  – SDG\_08\_11,  $x_3$  – SDG\_08\_20,  $x_4$  – SDG\_08\_30,  $x_5$  – SDG\_08\_40,  $x_6$  – SDG\_01\_41,  $x_7$  – SDG\_08\_60,  $x_8$  – SDG\_05\_40.

Source: authors' work based on Eurostat data.

Generally, we can observe the highest values of the variables relating to the implementation of SDG 8 in the Nordic countries, Czechia and Luxembourg. The lowest values are in southern European countries: Bulgaria, Greece and Romania. Quite an interesting situation can be observed in Malta, where one indicator (inactive population due to caring responsibilities) is of the lowest value, while a different one (fatal accidents at work) is the highest.

After applying the TOPSIS method, we calculate the synthetic variable presenting the fulfilment of SDG 8. On its basis we create rankings of EU countries according to the fulfilment of SDG 8 in the years 2002–2021. The rankings are presented in Table 3.

We can observe that the best situation with respect to the fulfilment of SDG 8 during the whole period was in Austria, Belgium, Denmark, Finland, Luxembourg, Sweden and the Netherlands. It is worth noting that the situation of these countries was stable throughout the whole analysed period. An interesting situation appeared in Ireland – until 2007, it was amongst the countries which achieved SDG 8 to the greatest extent. However, its position deteriorated during the financial crisis, but started to improve after 2011. In the final three years (2019–2021) of the analysis, Ireland occupied the highest position in this respect. Until 2009, Germany was in the middle in the ranking, but in 2010, the country reached the top ten and remained in this position until the end of the observation period. On the other hand, the ranking of France deteriorated after 2015. For most of the observation period, Italy ranked in the middle, although following 2016 its position deteriorated considerably. From that moment on, Italy was amongst the countries in the worst situation as far as the fulfilment of SDG 8 is concerned. Greece, Latvia, Poland (until 2010), Romania,

Slovakia, and Spain (starting 2012) occupied the lowest positions in the ranking. The situation in Poland worsened again in 2020, which might have been the effect of the COVID-19 pandemic. In 2002, Malta was one of the lowest-ranking countries with respect to the implementation of SDG 8, but after 2008, its position started to improve. Then, the COVID-19 pandemic caused the deterioration of its situation in this regard.

**Table 3.** Ranking of EU countries according to the fulfilment of SDG 8 in the years 2002–2021

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Austria	11	11	7	9	8	9	9	6	9	6	7	7	7	7	8	9	9	9	7	7
Belgium	9	9	10	6	7	7	6	7	7	7	6	6	6	6	6	8	7	7	8	9
Bulgaria	17	18	19	16	15	13	13	14	18	18	17	18	22	17	21	21	23	24	21	24
Croatia	24	21	25	17	19	21	18	23	19	24	26	25	23	24	24	22	21	23	17	15
Cyprus	21	25	26	24	23	19	16	12	13	11	15	17	17	20	17	17	19	19	22	17
Czechia	15	16	18	12	11	11	11	11	10	10	10	10	11	11	11	10	10	10	11	11
Denmark	2	1	1	1	1	1	1	1	2	3	2	1	1	1	1	1	2	4	2	2
Estonia	13	12	13	14	13	14	15	18	23	17	14	14	14	13	16	13	14	15	13	14
Finland	5	5	5	4	5	5	5	5	4	4	4	4	4	4	4	4	4	5	6	5
France	6	6	9	7	9	10	7	8	6	9	9	9	9	10	10	11	11	13	10	10
Germany	14	14	16	11	12	12	12	13	8	8	8	8	8	8	7	7	6	8	9	8
Greece	25	19	23	27	27	27	27	25	21	26	27	27	27	27	27	27	27	27	27	27
Hungary	16	15	17	19	18	15	17	16	15	14	12	13	13	14	13	15	15	14	14	13
Ireland	8	7	6	3	4	6	10	10	12	15	13	11	10	9	5	6	5	1	1	1
Italy	20	22	15	15	16	18	19	15	14	13	16	16	16	18	20	25	26	26	26	25
Latvia	19	20	21	21	22	23	24	26	27	27	25	19	21	22	23	19	20	21	20	18
Lithuania	18	17	14	20	21	17	22	19	26	25	20	21	20	16	14	16	17	17	18	22
Luxembourg	4	4	4	8	6	4	2	4	5	5	5	5	5	5	9	5	8	6	4	6
Malta	27	27	27	25	24	25	25	21	17	16	19	15	15	15	15	12	13	12	15	21
Netherlands	3	3	3	5	2	3	3	2	1	2	3	3	3	3	3	3	3	2	3	3
Poland	26	26	22	26	26	26	26	24	24	19	18	20	18	19	19	20	18	18	23	20
Portugal	7	8	11	13	14	16	14	17	16	20	22	22	19	21	18	18	16	16	16	16
Romania	23	24	24	23	25	24	23	20	22	23	21	23	24	25	25	24	24	22	19	23
Slovakia	22	23	20	22	20	20	20	27	25	22	23	24	25	23	22	23	22	20	24	19
Slovenia	10	10	8	10	10	8	8	9	11	12	11	12	12	12	12	14	12	11	12	12
Spain	12	13	12	18	17	22	21	22	20	21	24	26	26	26	26	26	25	25	25	26
Sweden	1	2	2	2	3	2	4	3	3	1	1	2	2	2	2	2	1	3	5	4

Source: authors' work based on Eurostat data.

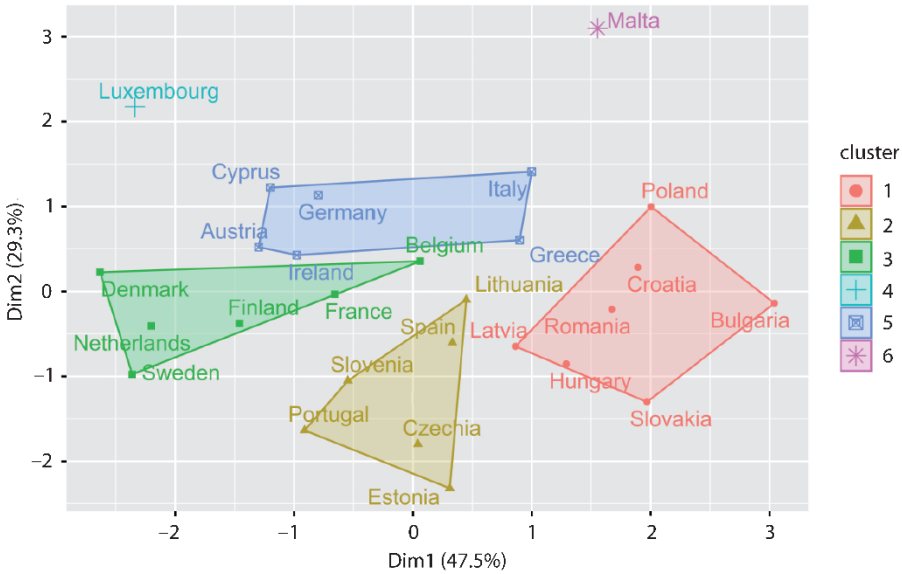
Generally, Austria, the Benelux Union and the Nordic countries occupied the top positions in the ranking illustrating the achievement of SDG 8. The lowest positions, on the other hand, were taken by Latvia, Poland, Slovakia, and the southern European countries. From among the post-communist countries, the closest to

achieving SDG 8 was Czechia. The position of this country was very close to the top 10 and remained stable during the whole studied period. Estonia, Hungary and Slovenia ranked in the middle. If we analyse the rankings during the crisis periods (i.e. the financial crisis of 2007–2009 and the COVID-19 pandemic in 2020–2021), no significant changes could be detected. It seems that the financial crisis influenced the rankings slightly more (with regard to the earlier mentioned Ireland, as well as Croatia and Slovakia). The COVID-19 pandemic did not change the rankings dramatically, although the positions of Malta, Poland and Slovakia did change.

In the next step of the analysis, we grouped the countries showing a similar level of SDG 8 achievement into homogeneous clusters. Since separate clusters can be created for each year, the full presentation of the analysis in such a form would exceed the capacity of the research. Therefore, the results of the cluster analysis refer to three selected years: 2002 (beginning of the observation period), 2009 (peak of the financial crisis) and 2020 (when the governments of European countries imposed the most severe pandemic-related restrictions).

In 2002, the optimal number of clusters was set at 6. Figure 1 presents the results of the cluster analysis, while the mean values of the indicators in each cluster are shown in Table 4.

**Figure 1.** Results of cluster analysis of EU countries with respect to SDG 8 implementation in 2002



Source: authors' work based on Eurostat data in the factoextra R package.

**Table 4.** Mean values of SDG 8 indicators in each cluster in 2002

Cluster no.	$x_1$	$x_2$	$x_3$	$x_4$	$x_8$
1 .....	3,851.28	22.54	23.00	61.04	21.17
2 .....	9,166.41	26.27	13.92	69.22	18.55
3 .....	25,518.72	21.17	10.02	73.23	12.20
4 .....	50,705.60	21.30	7.50	68.40	47.60
5 .....	20,787.99	22.19	13.62	67.93	40.95
6 .....	9,763.08	16.71	18.50	58.20	65.80

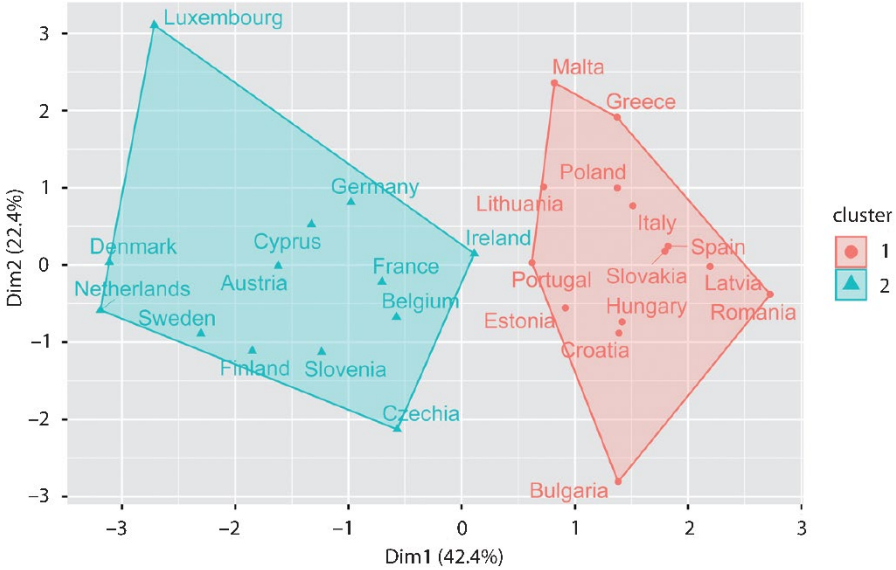
Note. As in Table 2.

Source: authors' work based on Eurostat data.

In 2002, the Nordic countries jointly with Belgium, France and the Netherlands created one cluster (number 3) with the generally highest values of the analysed indicators (with the exception of the GDP *per capita* and NEETs, whose values were higher in cluster 4, which included only Luxembourg). Malta itself created one cluster (number 6). Although most variables did not differ to a high degree across clusters, two indicators (investment share of GDP and inactive population due to caring responsibilities) were the worst for all analysed countries. Cluster 1 was the largest and consisted only of post-communist countries. It was characterised by the lowest GDP *per capita*, an average investment share, the largest share of NEETs, quite a low employment rate and a low share of the inactive population due to caring responsibilities. Cluster 2 mostly consisted of post-communist countries, together with Portugal and Spain. Its main feature was the highest investment share of GDP. Cluster 5 was internally the most heterogeneous. It was characterised by quite a high average GDP *per capita*, an average investment share of GDP, an average share of NEETs, a high employment rate and one of the highest shares of the inactive population due to caring responsibilities.

During the peak of the financial crisis (year 2009), the optimal number of clusters was set at 2. Figure 2 presents the clusters and Table 5 the mean values of the indicators.

**Figure 2.** Results of cluster analysis of EU countries with respect to SDG 8 implementation in 2009



Source: authors’ work based on Eurostat data in the factoextra R package.

**Table 5.** Mean values of SDG 8 indicators in each cluster in 2009

Cluster no.	$x_1$	$x_2$	$x_3$	$x_4$	$x_5$	$x_6$	$x_8$
1 .....	11,084.91	22.15	16.86	64.33	4.09	9.56	27.40
2 .....	29,658.21	22.14	11.08	72.58	1.85	6.03	20.51

Note. As in Table 2.

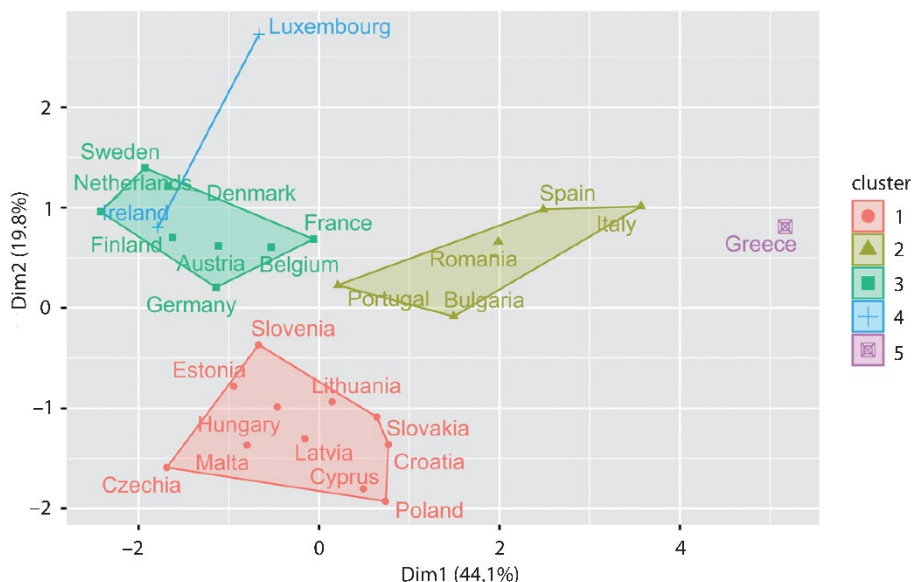
Source: authors’ work based on Eurostat data.

In 2009, EU countries were almost equally divided into two clusters. Cluster 1 contained most post-communist countries (except for Czechia and Slovenia) and most of the southern European states (Greece, Italy, Malta, Portugal and Spain). The remaining countries created cluster 2. As expected, the average values of the analysed indicators were higher in cluster 2 (except for the investment share of GDP, which was virtually identical in both clusters). When comparing these results with those of 2002, Czechia and Slovenia moved to the cluster of countries where the situation regarding the fulfilment of SDG 8 was better.

Finally, we present the results of the cluster analysis in 2020. Figure 3 illustrates our findings in this regard and the mean values of the indicators within each cluster are presented in Table 6. The optimal number of clusters was set at 5.



**Figure 3.** Results of cluster analysis of EU countries with respect to SDG 8 implementation in 2020



Source: authors' work based on Eurostat data in the *factoextra* R package.

**Table 6.** Mean values of SDG 8 indicators in each cluster in 2020

Cluster no.	$x_1$	$x_2$	$x_3$	$x_4$	$x_5$	$x_6$	$x_8$
1 .....	15,411.12	22.55	12.65	75.55	1.77	7.03	37.15
2 .....	15,546.27	19.88	17.26	67.94	3.38	11.32	16.20
3 .....	36,717.02	23.33	9.75	76.11	1.46	6.28	11.73
4 .....	70,486.25	28.24	10.95	72.10	1.55	8.95	22.45
5 .....	16,083.50	11.66	18.70	58.30	10.50	10.10	29.20

Note. As in Table 2.

Source: authors' work based on Eurostat data.

In 2020, clusters 3 and 4 consisted of countries which were most advanced in terms of their fulfilment of SDG 8. Cluster 3 included Austria, most of the Benelux Union (except for Luxembourg), France, Germany and the Nordic countries. There were only two countries in cluster 4 – Ireland and Luxembourg. In cluster 3 most indicators showed the highest values: the percentage of NEETs, the employment rate, the long-term unemployment rate, the in work at-risk-of-poverty rate and the share of inactive population due to caring responsibilities. Cluster 4, on the other hand, was characterised by the highest average GDP *per capita* and investment share of GDP. Most post-communist countries (except for Bulgaria and Romania, which were in cluster 2) were grouped in cluster 1 together with Malta and Cyprus. The

average values of the following indicators: investment share of GDP, percentage of NEETs and long-term unemployment rate ranked third among all the clusters. It had the lowest GDP *per capita*, second average employment rate and second in work at-risk-of-poverty rate. It also had the highest mean value of the share of the inactive population due to caring responsibilities. Cluster 2 (with the previously mentioned Bulgaria and Romania jointly with Italy, Portugal and Spain) showed the second lowest values of most indicators: GDP *per capita*, investment share of GDP, percentage of NEETs, employment rate, long-term unemployment rate. It also had the highest in work at-risk-of-poverty rate, but on the other hand, the second lowest share of the inactive population due to caring responsibilities. Cluster 5 contained only one country – Greece. Most indicators (investment share of GDP, percentage of NEETs, employment rate and long-term unemployment rate) in this cluster were of the lowest values, the in work at-risk-of-poverty rate and share of inactive population due to caring responsibilities were the second highest, while the average GDP *per capita* was the third best.

## 6. Conclusions

The aim of our research was to assess the extent to which EU countries fulfilled the targets set by SDG 8. The rankings obtained through the TOPSIS method showed that during the whole analysed period, Austria, the Benelux Union and the Nordic countries occupied the highest positions in rankings showing the implementation of SDG 8. The opposite situation was in the case of Greece, Latvia, Poland, Romania and Slovakia, and also in the final years of the analysis in Spain and Italy. These results were confirmed by the cluster analysis. The countries which proved most advanced in achieving the SDG 8 targets were grouped into separate clusters from those formed by countries which have a long road ahead towards reaching SDG 8. Our research, showing that Denmark, the Netherlands and Sweden are the leaders in SDG 8 achievement is consistent with the results of other research proving that these countries are the most advanced in the attainment of not only SDG 8, but all SDGs (Kuc-Czarnecka et al., 2023).

Our research demonstrates that despite the fact that less-developed regions of the EU (Greece, southern Italy, Portugal, Spain and post-communist countries) receive significant financial support for the achievement of the targets set by SDGs, the well-developed Western European countries still maintain a large advantage in this regard. The situation did not change much during the whole observation period. Some exceptions, however, could also be observed – Czechia managed to strengthen its position, while Slovenia had already held a high position, although at the end of the analysed period it slightly declined.

The crisis periods had little influence on the rankings. However, their impact on the results of the cluster analysis was more visible. It was more evident during the financial crisis of 2007–2009. The countries were separated into two clusters with a lower and higher degree of SDG 8 implementation. The differences between the countries within these clusters were so minor, that the further division into smaller ones did not occur.

The main policy recommendation based on our research is that the less-developed, post-communist and Southern European countries continue their efforts to fully implement the SDG 8 targets. The improvement of the situation of less-developed countries can be achieved particularly by means of increasing their GDP *per capita*, decreasing their long-term unemployment rate, decreasing the fraction of NEETs, and decreasing the number of inactive persons due to caring responsibilities – the differences between the most and least advanced countries were the highest with regard to the values of these indicators. The future area of research will also include other SDGs with the purpose of obtaining a full picture of the degree of their implementation in the EU, and especially in the post-communist, less-developed countries.

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