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ASSESSMENT OF THE IMPLEMENTATION OF SUSTAINABLE DEVELOPMENT GOAL 8 IN EUROPEAN UNION COUNTRIES USING SELECTED CLUSTER ANALYSIS METHODS

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Purpose: Sustainable Development Goal 8 focuses on promoting sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all. This poses a significant challenge for many countries, including the members of the European Union. Therefore, the aim of this article is to assess the implementation of SDG 8 by EU countries using selected clustering methods, namely Ward's method and the k-means method. The research period covers the year 2023.
Design/methodology/approach: The study is based on statistical data obtained from the Eurostat database. A total of 11 diagnostic variables describing SDG 8 were used, including both stimulants and destimulants. To evaluate the implementation of SDG 8 across EU countries in 2023, Ward's method and the k-means method were applied. The classification results were compared using a cluster matching matrix. The findings are presented in both graphical and tabular form.
Findings: The application of both methods resulted in the identification of five clusters of EU countries with similar levels of SDG 8 implementation. Characteristic features were defined for each group. The results indicate that EU countries differ significantly in their progress toward this goal. Germany, the Netherlands, and Ireland emerged as leaders in the implementation of SDG 8, achieving the most favorable values in as many as eight variables. In contrast, the group including Greece, Spain, Italy, and Romania did not stand out in terms of any of the variables related to SDG 8. The calculated cluster matching measures confirmed that Ward's method and k-means produced similar results.
Research limitations/implications: The study used only complete indicators characterizing Sustainable Development Goal 8 as published by Eurostat. Selecting appropriate variables in an international context is challenging; in this article, the selection was based on the availability and completeness of statistical data in the Eurostat database. An inappropriate or incomplete selection of variables may influence the final research results.
Practical implications: Monitoring changes in the implementation of SDG 8 by European Union countries is an important factor for assessing and verifying the effectiveness of policies and actions under the EU's Common Policy. The research provides a general overview of the current situation regarding the studied issue. Countries with lower levels of SDG 8 implementation may, for example, apply for support funds under the EU's cohesion policy or benefit from the experiences of more developed member states.

Originality/value: The originality of the article lies in the authors' individual approach to the research issues undertaken. The selection of diagnostic variables, research methods, the grouping of countries, and the evaluation of classification consistency were all authorial decisions. This approach enriches the research methodology. The results may serve as a foundation for expanding knowledge in this area, preparing and applying more advanced research methods, or broadening the scope of research conclusions.
Keywords: SDG 8, Ward's method, k-means method, country clustering, classification consistency measures.
Category of the paper: Research paper.

Introduction

The issue of sustainable development continues to gain popularity. It is the subject of numerous scientific analyses and studies, as well as active public debate. This concept is highly significant for both the economy and society, as it integrates economic, social, and environmental issues in a way that ensures mutual reinforcement (Fura et al., 2025; Kryk, 2017).

The most recent step toward defining and refining the goals and principles of sustainable development and the methods for achieving them was the adoption of the 2030 Agenda by the United Nations General Assembly in 2015 (The 2030 Agenda…, 2015). Within this framework, UN member states agreed upon the Sustainable Development Goals (SDGs), which serve as benchmarks for achieving the overarching objective of sustainable development (Fonseca et al., 2020). The SDGs replaced the Millennium Development Goals, which had not been fully achieved by 2015. Unlike their predecessors, the SDGs are intended to apply universally—not only to developing countries but to all nations (Rokicka, Woźniak, 2016).

The 2030 Agenda outlines 17 Sustainable Development Goals, broken down into 169 related targets. These goals are medium-term in nature, with a timeframe extending from 2015 to 2030. They are designed to stimulate action in areas of critical importance: people, planet, prosperity, peace, and partnership (Raczkowska et al., 2021).

The SDGs address a wide range of issues, including the eradication of poverty and hunger, access to clean water and sanitation, quality education and lifelong learning, gender equality and the empowerment of women, access to affordable and clean energy, full employment, the development of resilient infrastructure and industrialization, climate change mitigation, protection of oceans and terrestrial ecosystems—especially forests. These are global objectives, rooted in the United Nations' concern for humanity as a whole. As Górka (2023) notes, the goals can also be translated into regional and national priorities, including the responsibilities of local governments and enterprises.

Among these 17 Sustainable Development Goals, SDG 8 aims to promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all (Chigbu, Nekhwevha, 2023).

The aim of the article is to assess the implementation of Sustainable Development Goal 8 (SDG 8) by European Union countries using selected cluster analysis methods, namely Ward's method and the k-means method, and to compare the results obtained. The research covers the year 2023, which is the most recent period for which complete and comparable data are available.

The core research problem focuses on identifying the differences between EU countries in terms of achieving SDG 8. To analyze the level of implementation and disparities among countries, indicators from the Eurostat database were used.

The article addresses the following research questions:

1. Which EU countries exhibit a similar level of SDG 8 implementation?
2. What characteristics define the groups of countries with a comparable level of SDG 8 implementation according to Ward's method and the k-means method?
3. How consistent are the clustering results between the two methods?

The paper is structured as follows: section 2 gives an overview of SDG 8. Section 3 describes the research methods, the results of our analyses are shown in section 4. Section 5 presents discussion and finally, section 6 concludes.

SDG 8 in the literature review – conceptual explanation

As previously mentioned, this study focuses on one of the 17 Sustainable Development Goals—namely, SDG 8. This goal emphasizes the importance of sustained economic growth and high levels of economic productivity as key drivers in creating well-paid, high-quality jobs and ensuring efficient resource management.

One of the core objectives within SDG 8 is to achieve "economic growth" through the concept of "decent work" in all UN member states (Küfeoğlu, 2022). The concept of decent work was introduced by the International Labour Organization (ILO), which has been operating since 1919 and currently includes 181 member states, including Poland. According to the ILO, decent work is defined as "opportunities for women and men to obtain decent and productive work, in conditions of freedom, equity, security and human dignity". This means that decent work encompasses not only fair wages, but also employment security, safe working conditions, and jobs that respect the rights and needs of workers as individuals (https://www.ilo.org/about-ilo).

The ILO developed the Decent Work Agenda**,** which aims to improve the economic conditions of employment and promote equal opportunities for decent employment for both women and men. It also monitors whether countries comply with the obligations stemming from ratified ILO conventions and investigates complaints against entities violating international labor rights (https://stat.gov.pl/statystyka-miedzynarodowa/instytucjeorganizacje-miedzynarodowe/onz-organizacja-narodow-zjednoczonych/ilo-miedzynarodowa-organizacja-pracy/).

SDG 8 thus highlights the importance of creating opportunities for full and decent employment for all, including people with disabilities, ensuring gender equality, promoting workers' rights**,** and guaranteeing safe and secure working environments**.**

As Rodgers (2009) states, the increase in decent employment is directly related to economic growth*,* reinforcing the idea that labor market improvements and social well-being are intrinsically linked with the broader goals of sustainable economic development.

Economic growth can be defined as the increase in consumption driven by population growth and the ability to meet that consumption through advances in technology and government incentives. Economic activity may be stimulated by various initiatives, including government actions ranging from tax optimization and protection of free markets to investments in infrastructure and education (Bleys, Whitby, 2015).

Ensuring equal access to the labor market—and, by extension, decent work—for all social groups is a key element of sustainable development and a foundation for building an inclusive society. Prolonged exclusion from the labor market can lead to poverty and social marginalization. Reducing unemployment and implementing mechanisms that encourage workforce participation significantly contribute to accelerating economic development in the long term. A high level of employment is crucial for socio-economic cohesion (Mikuła, Komorowska, 2021). Between 2016 and 2030, it is estimated that 470 million jobs will be needed for new labor market entrants (https://www.un.org.pl/cel8).

Unemployment is one of the core challenges that SDG 8 seeks to address. Across the European Union, the unemployment rate saw a notable decline in 2023 compared to previous years. For instance, in 2014, the unemployment rate was 5.4%, while by 2023 it had dropped to 2.1%. Poland consistently ranked among the countries with the lowest unemployment rates in the EU. As of December 2023, Poland held the second-lowest unemployment rate in the EU, at 2.7% (https://www.gov.pl/web/rodzina/polska-na-drugim-miejscu-z-najnizsza-stopa-bezrobocia-w-ue-wedlug-eurostatu).

These findings reinforce the importance of employment-related policies in achieving SDG 8, and they highlight the role of labor market inclusion and productivity in promoting sustainable and inclusive economic growth. Another important aspect discussed in the context of achieving Sustainable Development Goal 8 is gender equality in the labor market. In most analyses, women face more barriers to accessing employment, earn less than men, even though they tend to be better educated (Mikuła, Komorowska, 2021).

According to data published by the European Parliament, the average gender pay gap in the EU was 12% in 2023. Among EU countries, the highest gender pay gaps were observed in Latvia (19.5%), Austria (18.3%), Hungary (17.8%), Czechia (17.6%), and Germany (17.6%). In contrast, countries with the smallest pay differences between women and men included Belgium (0.7%), Italy (2.2%), Romania (3.8%), Malta (5.1%), and Slovenia (5.4%). In Poland, the gender pay gap stood at 7.8%, while in Luxembourg, women and men earned the same on average (https://www.europarl.europa.eu/topics/pl/article/20200109STO69925/luka-placowa-miedzy-kobietami-a-mezczyznami-definicja-fakty-i-przyczyny).

The situation of women in the labor markets across the European Union remains highly unequal. On one hand, the professional potential of women is steadily increasing, yet on the other, its utilization within European labor markets still leaves much to be desired. Strengthening women's rights at all levels—from access to education to equal pay based on productivity—is a fundamental challenge for the European Union. Every member state is obligated to operate under anti-discrimination regulations stemming from the Treaty establishing the European Community, as well as a series of EU directives. The actions undertaken by the European Union aim not only to promote equal opportunities for women and men in the labor market, but also to prevent the emergence of social problems, such as female unemployment (Trębska, 2018). Guaranteeing equal treatment for women in economic and political matters will enhance sustainable economic development and deliver broader social benefits on a global scale.

Assumptions of Research Methods

In evaluating the implementation of the 8th Sustainable Development Goal in EU countries in 2023, the Ward's method and the k-means method were used.

Ward's method belongs to the so-called hierarchical agglomerative methods, described using the central agglomeration procedure (Grabiński, 2003; Lance, Williams, 1967; Lance, Williams, 1967a; Ward, 1963).

The starting point is the distance matrix D, representing distances d_{i} between the classified objects O_1 , O_2 , ..., O, i.e., the distances between points in a multidimensional space. In practice, the most commonly used measure is the Euclidean distance, expressed as follows (Nowak, 1990):

$$d_{ik} = \sqrt{\sum_{j=1}^{m}\left(z_{ij} - z_{kj}\right)^2} \qquad \text{(i, k = 1, 2, ..., n).} \tag{1}$$

By calculating the distances between the identified objects, a distance matrix is obtained (Kolenda, 2006):

$$D = \begin{bmatrix} 0 & d_{12} & \dots & d_{1n} \\ d_{21} & 0 & \dots & d_{2n} \\ . & . & . & . \\ d_{n1} & d_{n2} & \dots & 0 \end{bmatrix}. \quad (2)$$

The algorithm of the central agglomeration procedure is as follows (Nowak, 1990):

1. Each object O_i (i = 1, 2, ..., n) is treated as a single-element group.
2. The minimum value in the distance matrix is identified:

$$d_{pq} = \min_{i,j} \{d_{ij}\} \text{ (i , j = 1, …, n)}, \quad (3)$$

   where n – denotes the number of currently existing groups (in the first step, n equals the number of objects).
3. The objects O_p and O_q are treated as single-element groups. The clusters A_p and A_q are merged into a new two-element group A_r:

$$A_r = A_p \cup A_q,$$

4. From the distance matrix D, the row and column with index q are removed, and n is updated as: $n:=n-1$,
5. The distances d_{ir} between the newly formed group A_r and all remaining groups A_i are calculated according to the chosen method. The values d_{ir} are inserted into matrix D in place of the p-th row (and elements d_{ri} are inserted into the p-th column).
6. Steps 2 to 5 are repeated until all objects are merged into a single group.

The general formula for updating the distance matrix during the merging of groups A_p and A_q into a new group A_r for hierarchical agglomerative methods is as follows (Nowak, 1990):

$$d_{ir} = a_p d_{ip} + a_q d_{iq} + b d_{pq} + c\left|d_{ip} - d_{iq}\right|, \quad (4)$$

where:

d_{ir} – distance between groups A_i and A_r,

d_{ip} – distance between groups A_i and A_p,

d_{iq} – distance between groups A_i and A_q,

d_{pq} – distance between groups A_p and A_q,

a_p, a_q, b, c – transformation parameters characteristic for different clustering methods,

N_i, N_p, N_q, N_r – number of elements in groups A_i, A_p, A_q, and A_r, respectively.

Ward's method involves merging such clusters A_p and A_q that, as a whole, minimize the total within-cluster sum of squares (i.e., the sum of squared distances from the centroid of the new, merged cluster).

The transformation of distance matrix elements is performed according to the following formula (Nowak, 1990):

$$d_{ir} = \frac{N_i + N_p}{N_i + N_r} d_{ip} + \frac{N_i + N_q}{N_i + N_r} d_{iq} - \frac{N_i}{N_i + N_r} d_{pq} \tag{5}$$

Ward's method is characterized by high effectiveness, understood as the ability to accurately recognize the true structure of objects in a multidimensional classification space (Sokołowski, 1992).

In the k-means method (Bock, 2007; Dobosz, 2004; Everitt et al., 2011; Jain, 2010; Stanisz, 2007), the number of clusters into which the set of observations will be divided is assumed in advance. Thus, the algorithm starts with *k* clusters and then reassigns objects between these clusters with the goal of:

1. Minimizing within-cluster variability.
2. Maximizing between-cluster variability.

Clustering using the *k*-means method is therefore an iterative procedure—in each iteration, some objects may be reassigned to different clusters. A key advantage of the k-means method is that it ensures the formation of k clusters that are as distinct from one another as possible. However, the need to predefine the number of clusters may be considered a drawback, particularly when the structure of the dataset is unknown and there is no basis for hypothesizing the expected number of clusters.

The *k*-means clustering process continues through successive iterations until stabilization (i.e., when no further changes in object assignment occur) or until a pre-specified maximum number of iterations is reached. The method is sensitive to outliers, and the proper selection of the number of clusters is crucial for its effectiveness (Sokołowski, Czaja, 2014).

Clustering methods can produce groups with similar or different object compositions, making it particularly interesting to compare the classification results obtained using different clustering approaches.

An interesting measure for comparing classification results was proposed by Pociecha, Podolec, Sokołowski and Zając (1988). This method introduces a classification agreement matri**x** (also known as a contingency or matching matrix):

$$P = P_A + P_B, \tag{6}$$

where P_A, P_B – assignment matrices for classifications *A* and *B*, respectively.

In the assignment matrix P_A, the element at position (i, j) equals 1 if objects *i* and *j* belong to the same subset, and 0 if they belong to different subsets. In a similar manner, the assignment matrix P_B is constructed for the second classification.

Matrix *P* is a square matrix of size $(n \times n)$, where the elements 0, 1, and 2 indicate, respectively, that a pair of objects:

- do not form a common subgroup in either classification,
- were assigned differently in the two classifications, or
- were assigned identically in both classifications.

If classification A results in k_1 subsets and classification B results in k_2 subsets, the classification agreement measure (W_Z) is defined by the following formula (Pociecha et al., 1988):

$$W_Z = \frac{2(z_2 - n)}{\sum_{i=1}^{k_1}\left(n_i^2 - n_i\right) + \sum_{j=1}^{k_2}\left(n_j^2 - n_j\right)} \tag{7}$$

where:

z_2 – the number of twos (i.e., matching pairs) in matrix P,

n_i – the size of the i-th subgroup in classification A,

n_j – the size of the j-th subgroup in classification B,

n – the total number of objects.

W_Z is a normalized measure ranging from 0 to 1. The higher the value of W_Z, the greater the agreement between the two classifications. For identical classifications, $W_Z = 1$. On the other hand, $W_Z = 0$ when one classification consists of n single-element groups, and the other consists of one group containing all elements in the dataset.

Another commonly used measure in empirical studies for comparing the results of two different partitions is the Adjusted Rand Index (ARI).

The Adjusted Rand Index for classifications $P^{(t)}$ and $P^{(q)}$ is calculated using the formula (Hubert, Arabie, 1985; Rand, 1971; Steinley, 2004; Walesiak, 2011):

$$R_{HA} = \frac{\sum_{r,s}\binom{n_{rs}}{2} - \sum_{r}\binom{n_{\bullet r}}{2}\sum_{s}\binom{n_{s\bullet}}{2}\Big/\binom{n}{2}}{\frac{1}{2}\left[\sum_{r}\binom{n_{\bullet r}}{2} + \sum_{s}\binom{n_{s\bullet}}{2}\right] - \sum_{r}\binom{n_{\bullet r}}{2}\sum_{s}\binom{n_{s\bullet}}{2}\Big/\binom{n}{2}} \tag{8}$$

where:

r (s) – the number of classes in partition $P^{(t)}$ $P^{(q)}$,

n_{rs} – the number of objects that simultaneously belong to classes $P_r^{(t)}$ and $P\square^{(q)}$,

$n_{\bullet r}$ – the number of objects in class $P_r^{(t)}$,

$n_{s\bullet}$ – the number of objects in class $P\square^{(q)}$.

The Adjusted Rand Index (ARI) is a statistical measure used to evaluate the similarity between two clustering results while adjusting for random chance. It improves upon the Rand Index by accounting for the expected similarity of all pairwise assignments due to chance.

The ARI score ranges from -1 to 1:

- 1 indicates a perfect match between the two clustering results,
- 0 suggests that the similarity between clusters is no better than random chance.

Negative values indicate that the agreement is less than what would be expected by random assignment.

Research Results

In the study on the implementation of Sustainable Development Goal 8 in the European Union countries in 2023, the following variables were taken into account:

X1 – Real GDP per capita (euro per capita) [SDG_08_10] (S),
X2 – Investment share of GDP by institutional sectors (% of GDP) [SDG_08_11] (S),
X3 – Young people neither in employment nor in education and training (% of population aged 15 to 29) [SDG_08_20] (D),
X4 – Young people neither in employment nor in education and training (NEET), by citizenship [SDG_08_20a] (D),
X5 – Employment rate (% of population aged 20 to 64) [SDG_08_30] (S),
X6 – Employment rate, by citizenship [SDG_08_30a] (S),
X7 – Long-term unemployment rate (% of active population) [SDG_08_40] (D),
X8 – Fatal accidents at work per 100,000 workers, by sex [SDG_08_60] (D),
X9 – In-work at-risk-of-poverty rate (% of employed persons aged 18 or over) [SDG_01_41] (D),
X10 – Inactive population due to caring responsibilities (% of inactive population aged 20 to 64) [SDG_05_40] (D),
X11 – Raw material consumption (RMC) [SDG_12_21] (D).

Variables X1, X2, X5, and X6 are stimulants (S), while the remaining variables are destimulants (D).

These terms were introduced into the literature by Hellwig (1968), defining stimulants as characteristics whose high values are desirable from the assumed point of view (e.g., the level of sustainable development), while low values are undesirable. On the other hand, destimulants are characteristics whose low values are desirable in relation to the studied phenomenon, while high values are considered undesirable.

The values of variables X1-X11 for the year 2023 were obtained from the Eurostat website (https://ec.europa.eu/eurostat/data/database). Calculations were performed using Excel, STATISTICA, and Python.

Figure 1 presents the results of the clustering of EU countries in terms of the level of implementation of Sustainable Development Goal 8 in 2023 using Ward's method.

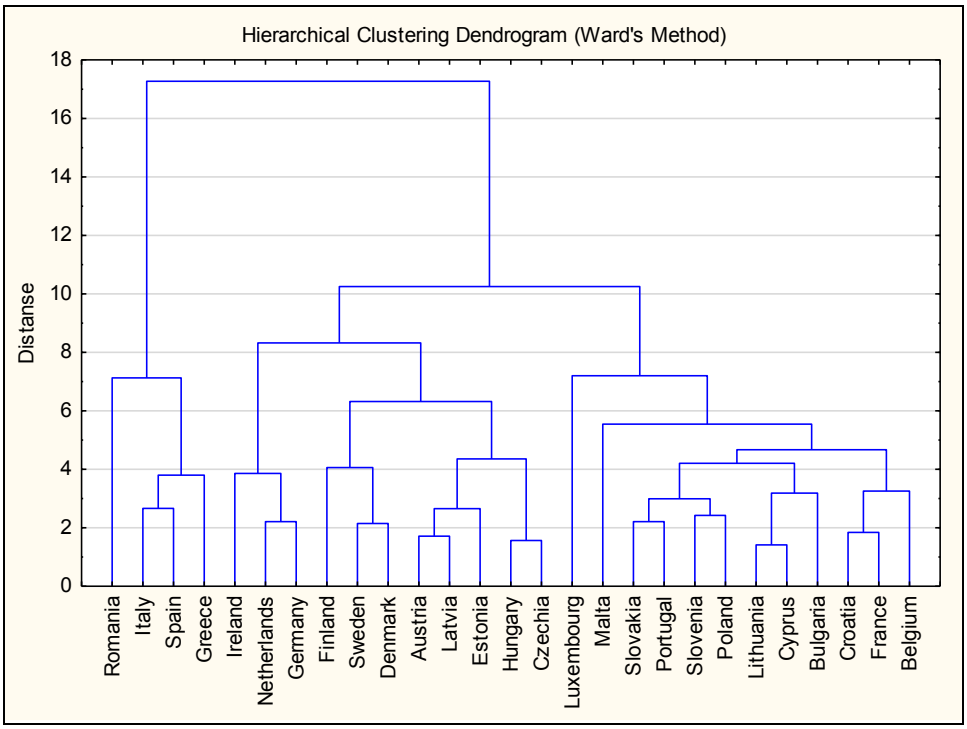

Figure 1. Clustering of EU countries by the level of implementation of Sustainable Development Goal 8 using Ward's method in 2023.

Source: Author's own elaboration.

Based on the dendrogram shown in Figure 1, the EU countries were divided into five groups with similar levels of implementation of Sustainable Development Goal 8 in 2023 (Table 1).

Table 1.
Groups of EU countries with similar levels of implementation of Sustainable Development Goal 8 in 2023

Group	Ward's Metod	K-means method
I	Belgium, France, Croatia, Bulgaria, Cyprus, Lithuania, Poland, Slovenia, Portugal, Slovakia, Malta	Bulgaria, France, Croatia, Cyprus, Latvia, Lithuania, Malta, Poland, Portugal, Slovakia
II	Luxembourg	Greece, Spain, Italy, Romania
III	Czechia, Hungary, Estonia, Latvia, Austria, Denmark, Sweden, Finland	Germany, Ireland, Netherlands
IV	Germany, Netherlands, Ireland	Belgium, Czechia, Denmark, Estonia, Hungary, Austria, Slovenia, Finland, Sweden
V	Greece, Spain, Italy, Romania	Luxembourg

Source: Author's own elaboration.

It should be noted that the composition of the country groups obtained using the two clustering methods—Ward's method and k-means—is very similar. The differences between group assignments affected the following countries: Belgium and Slovenia (Group I – Ward's method; Group IV – k-means method), Latvia (Group III – Ward's method; Group I – k-means method). Identical country compositions were found for the following group pairs: Group II (Ward's method) and Group V (k-means); Group IV and Group III and Group V and Group II.

It also seems interesting to highlight the characteristic features of the formed groups. Table 2 presents the countries included in each group along with the arithmetic means of the input variables for the countries in each group. The bolded values indicate the most favorable values of the respective input variables.

Table 2.
Average values of input variables in EU country groups in 2023 according to Ward's method

Group	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
I	21 588.18	21.10	10.86	10.42	76.70	76.75	1.98	2.55	7.89	**0.30**	16.59
II	**83 320.00**	18.13	8.50	7.90	74.80	71.10	1.70	2.78	14.80	**0.30**	32.05
III	29 115.00	**25.23**	9.19	8.84	79.98	80.80	1.26	1.87	6.63	**0.30**	24.43
IV	50 816.67	21.59	**7.33**	**6.23**	**81.23**	**82.30**	**0.87**	**0.67**	**5.77**	0.77	**10.78**
V	21 052.50	21.09	15.90	15.15	68.23	68.58	4.23	1.74	11.60	0.48	15.76

Source: Author's own elaboration.

It should be noted that Group I, which included 11 countries—Belgium, France, Croatia, Bulgaria, Cyprus, Lithuania, Poland, Slovenia, Portugal, Slovakia, and Malta—showed a favorable situation only in terms of variable X10: *Inactive population due to caring responsibilities (% of inactive population aged 20 to 64)*.

Luxembourg, classified in Group II, clearly stood out in terms of variable X1: *Real GDP per capita*, reaching a value of €83,320 per capita.

A characteristic feature of countries in Group III (Czechia, Hungary, Estonia, Latvia, Austria, Denmark, Sweden, Finland) was a relatively high value of variable X2: *Investment share of GDP by institutional sectors (% of GDP)*, along with a low value of variable X10: *Inactive population due to caring responsibilities (% of inactive population aged 20 to 64)*.

In contrast, Germany, the Netherlands, and Ireland emerged as leaders in the implementation of SDG 8, achieving the most favorable values for as many as eight variables: X3, X4, X5, X6, X7, X8, X9, and X11.

The final Group V, which included Greece, Spain, Italy, and Romania, did not stand out in any particular way regarding the variables related to SDG 8.

When evaluating the classification of EU countries based on the implementation of SDG 8 using the k-means method, a high degree of similarity can be observed in the composition of the individual groups compared to the division obtained with Ward's method. This similarity is also illustrated in Figure 2, which presents the average values of the input variables for each group of countries.

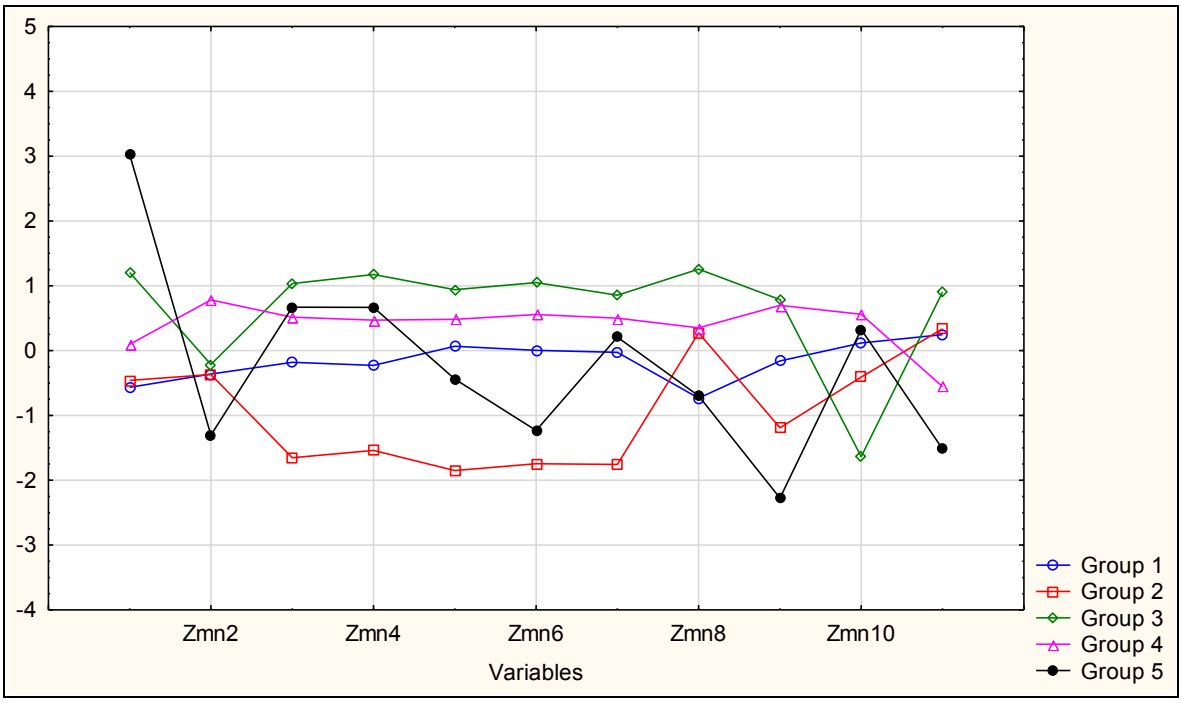

Figure 2. Average values of input variables in groups of EU countries by level of implementation of Sustainable Development Goal 8, formed using the k-means method in 2023.

Source: Author's own elaboration.

The consistency of the clustering results of EU countries in terms of the implementation of Sustainable Development Goal 8 in 2023 was assessed using the Pociecha, Podolec, Sokołowski, and Zając measure (Formula 7) and the Adjusted Rand Index (Formula 8).

The calculated value of the first indicator was 0.656, while the value of the second measure was 0.644, indicating a fairly high level of agreement between the clustering results.

This suggests that in empirical research, either of the applied clustering methods can be reliably used.

Discussion

Sustainable development is a fundamental objective of the European Union, and the 17 goals set out in the 2030 Agenda have served as a catalyst for numerous efforts aimed at achieving them by the year 2030. Among these goals, SDG 8—*Decent Work and Economic Growth*—has been the subject of a variety of studies in the literature.

One such study was conducted by Bieszk-Stolorz and Dmytrów (2023), whose aim was to perform a static geographical comparison of the level and dynamics of SDG 8 implementation across EU countries between 2002 and 2021, with particular consideration of the COVID-19 pandemic. The authors used the COPRAS method, Dynamic Time Warping (DTW), and hierarchical clustering. Their results confirmed the geographical disparities in SDG 8

implementation, which are consistent with the findings presented in this article. Specifically, Nordic and Western European countries exhibited the highest levels of SDG 8 implementation, whereas Southern European countries (e.g., Greece, Spain, Italy, and Romania) showed the lowest performance.

Mikuła and Komorowska (2021) reported similar findings. They evaluated the advancement of SDG 8 implementation using multivariate analysis for the years 2015 and 2019. Their methodology was based on a synthetic variable calculated using the sum of standardized indicators assigned to the goal. This allowed them to construct a ranking of EU member states. Consistent with other research, countries such as the Netherlands, Sweden, and Denmark were found to perform best in achieving SDG 8, while Romania, Greece, Spain, and Italy ranked the lowest. The largest improvement in the ranking between 2015 and 2019 was observed in Ireland (up by 7 positions), whereas Luxembourg experienced the most significant drop.

Another study focusing on SDG 8 was conducted by Carlsen (2021) for the years 2010, 2015, and 2019. It focused on five key indicators: real GDP (GDP), investment share of GDP by institutional sectors (INV), young people neither in employment nor in education and training (NEET), employment rate (EmpR), and long-term unemployment rate (LtUR). Carlsen analyzed the relationships among the 27 EU member states, using the EU-27 average as a reference point to highlight each country's level of alignment with SDG 8. The findings helped identify which countries were performing above or below the EU average and suggested areas where specific countries might need additional support to improve their relative position. These conclusions are consistent with the results presented in this article.

Regardless of the methods applied, and based on the Eurostat (2024) data, it can be concluded that the European Union has made significant progress in achieving the Sustainable Development Goals, including SDG 8. The results confirm that, despite differences among countries, positive changes have occurred in most EU member states in the pursuit of the goal of "Decent Work and Economic Growth".

Conclusion

When studying sustainable development, it is essential to recognize that it is a complex and multidimensional phenomenon. Although the concept of sustainable development has evolved over time, its core principles and objectives have contributed to more conscious behavior aligned with existing limitations. In the context of global change, humanity cannot afford to ignore environmental concerns and social exclusion. Therefore, the issue of sustainable development must not only remain at the forefront of awareness but must also translate into concrete actions - both at the national and international policy level, as well as among societies of individual countries. The disparities between countries should gradually diminish, a process

largely shaped by EU sustainable development policy. However, this is a slow and long-term process.

It was therefore reasonable to conduct an analysis and assessment of the implementation of Sustainable Development Goal 8 by European Union countries using selected cluster analysis methods, namely Ward's method and the k-means method. The research results showed that the groupings of countries obtained using these methods are very similar. Germany, the Netherlands, and Ireland are the leaders in achieving this sustainable development goal, attaining the most favorable values for as many as 8 variables characterizing this goal.

Luxembourg formed a separate group, standing out in terms of variable X1 – *Real GDP per capita.* A relatively high value of variable X2 – *Investment share of GDP by institutional sectors (% of GDP*), along with a low value of variable X10 – *Inactive population due to caring responsibilities (% of inactive population aged 20 to 64)*, characterized the following group of countries: Czechia, Hungary, Estonia, Latvia, Austria, Denmark, Sweden, and Finland.

Greece, Spain, Italy, and Romania constituted a group of countries that did not stand out in any particular way in terms of the variables defining Sustainable Development Goal 8.

It should be noted that the clustering methods used in the study – Ward's method and k-means – produced similar results, as indicated by the applied measures of clustering agreement, such as the Pociecha, Podolec, and Sokołowski measures, as well as Zając's measure and the adjusted Rand index.

Monitoring changes in the implementation of SDG 8 across EU countries is a critical factor for assessing and verifying the effectiveness of actions taken under the Common EU Policy.

This study addresses a research gap and contributes to a deeper understanding of the essence of sustainable development, offering practical insights. Nevertheless, it is important to acknowledge certain limitations of the study. Only complete indicators characterizing SDG 8, as published by Eurostat, were used. The authors are aware that the selection of variables in an international context is challenging and was primarily determined by the availability and completeness of statistical data in the Eurostat database.

It should be noted, however, that these variables are reliable and, as emphasized by Bilek-Steindl and Url (2022), go beyond conventional economic indicators, extending them to encompass inclusive and sustainable economic growth as well as decent work for all. Indicators that reflect a broader perspective on the labor market—such as "inactive population due to caring responsibilities", or those that include information on "fatal occupational accidents" or the "in-work at-risk-of-poverty rate"—now complement traditional economic variables.

References

1. Bieszk-Stolorz, B., Dmytrów, K. (2023). Decent work and economic growth in EU countries—static and dynamic analyses of sustainable development goal 8. *Sustainability, 15,* 13327. https://doi.org/10.3390/ su151813327
2. Bilek-Steindl, S., Url, T. (2022). Nowcasting and monitoring SDG 8. *Empirica*, *49*(2), 313-345.
3. Bleys, B., Whitby, A. (2015). Barriers and opportunities for alternative measures of economic welfare. *Ecol. Econ., 117,* 162-172. https://doi.org/10.1016/j.ecolecon. 2015.06.021
4. Bock, H.H. (2007). Clustering Methods: A History of k-Means Algorithms. In: P. Brito, G. Cucumel, P. Bertrand, F. de Carvalho (Eds.), *Selected Contributions in Data Analysis and Classification.* Springer.
5. Carlsen, L. (2021). Decent Work and Economic Growth in the European Union. A partial order analysis of Eurostat SDG 8 data. *Green Finance, 3(4),* 483-494. https://doi.org/10.3934/GF.2021022
6. Chigbu, B.I., Nekhwevha, F. (2023.) Exploring the concepts of decent work through the lens of SDG 8: addressing challenges and inadequacies. *Frontiers in Sociology, 8,* 1266141. https://doi.org/10.3389/fsoc.2023.1266141
7. Dobosz, M. (2004). *Wspomagana komputerowo statystyczna analiza wyników badań*. Warszawa: EXIT Academic Publishing House.
8. Eurostat (2024). https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20240618-2
9. Everitt, B.S., Landau, S., Leese, M., Stahl, D. (2011). *Cluster analysis.* New York: John Wiley & Sons. Ltd., 330.
10. Fonseca, L.M., Domingues, J.P., Dima, A.M. (2020). Mapping the Sustainable Development Goals Relationships. *Sustainability, 12,* 3359. https://doi.org/10.3390/ su12083359.
11. Fura, B., Karasek, A., Hysa, B. (2025). Statistical assessment of digital transformation in European Union countries under sustainable development goal 9. *Qual. Quant., 59,* 937-972. https://doi.org/10.1007/s11135-024-01972-0
12. Górka, K. (2023). Ewolucja koncepcji rozwoju zrównoważonego i trwałego oraz jej wdrażanie. In: M. Proniewski, D. Kiełczewski (Eds), *Mechanizmy zrównoważonego rozwoju*. Białystok: University of Białystok Publishing House.
13. Grabiński, T. (2003). Analiza taksonometryczna krajów Europy w ujęciu regionów. Kraków: AE w Krakowie.

14. Hellwig, Z. (1968). Zastosowanie metody taksonomicznej do typologicznego podziału krajów ze względu na poziom ich rozwoju i strukturę wykwalifikowanych kadr. *Przegląd Statystyczny, no. 4.*
15. https://stat.gov.pl/statystyka-miedzynarodowa/instytucjeorganizacje-miedzynarodowe/onz-organizacja-narodow-zjednoczonych/ilo-miedzynarodowa-organizacja-pracy/, 14.07.2025.
16. https://www.europarl.europa.eu/topics/pl/article/20200109STO69925/luka-placowa-miedzy-kobietami-a-mezczyznami-definicja-fakty-i-przyczyny, 14.07.2025.
17. https://www.gov.pl/web/rodzina/polska-na-drugim-miejscu-z-najnizsza-stopa-bezrobocia-w-ue-wedlug-eurostatu, 14.07.2025.
18. https://www.ilo.org/about-ilo, 14.07.2025.
19. https://www.un.org.pl/cel8, 02.07.2025.
20. Hubert, L., Arabie, P. (1985). Comparing partitions. *Journal of Classification, 2,* 193-218.
21. Jain, A.K. (2010). Data clustering: 50 years beyond K-means. *Pattern recognition letters*, *31(8),* 651-666.
22. Kolenda, M. (2006). *Taksonomia numeryczna. Klasyfikacja, porządkowanie i analiza obiektów wielocechowych.* Wrocław: AE Publishing House in Wrocław.
23. Kryk, B. (2017). Cele społeczne zrównoważonego rozwoju. Polska na tle UE. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu*, *no. 465.*
24. Küfeoğlu, S. (2022). *Emerging technologies: value creation for sustainable development*. Springer Nature.
25. Lance, G.M., Williams, W.T. (1967). A General Theory of Classificatory Sorting Strategies I. Hierarchical System. *Computer Journal, no. 9.*
26. Lance, G.M., Williams, W.T. (1967a). A General Theory of Classificatory Sorting Strategies II. Clustering Systems. *Computer Journal, no. 10.*
27. Mikuła, A., Komorowska, D. (2021). Realizacja ósmego celu zrównoważonego rozwoju – godna praca i wzrost gospodarczy a sytuacja na rynku pracy w krajach Unii Europejskiej. In: A. Siedlecka, D. Guzal-Dec (Eds.), *Rynek pracy wobec wyzwań przyszłości – ujęcie interdyscyplinarne* (pp. 226-242). Biała Podlaska: State School of Economics in Biała Podlaska.
28. Nowak, E. (1990). *Metody taksonomiczne w klasyfikacji obiektów społeczno-gospodarczych*. Warszawa: PWE.
29. Pociecha, J., Podolec, B., Sokołowski, A., Zając, K. (1988). *Metody taksonomiczne w badaniach społeczno-ekonomicznych*. Warszawa: PWN.
30. Raczkowska, M., Mikuła, A., Utzig M. (2021). *Zrównoważony rozwój w obszarze społecznym w Unii Europejskiej.* Warszawa: SGGW Publishing House.
31. Rand, W.M. (1971). Objective criteria for the evaluation of clustering methods. *Journal of the American Statistical Association*, *66(336),* 846-850.
32. Rodgers, G. (2009). The goal of decent work. *IDS Bull., 39,* 63-68.

33. Rokicka, E., Woźniak, W. (2016). *W kierunku zrównoważonego rozwoju. Koncepcje, interpretacje, konteksty*. Łódź: University of Łódz Publishing House.
34. Sokołowski, A. (1992). Empiryczne testy istotności w taksonomii. *ZN AE w Krakowie. Seria specjalna. Monografie, no. 108.*
35. Sokołowski, A., Czaja, M. (2014). Efektywność metody k-średnich w zależności od separowalności grup. *PN UEK we Wrocławiu, no. 327, Taksonomia, 22. Klasyfikacja i analiza danych – teoria i zastosowania.*
36. Stanisz, A. (2007). *Przystępny kurs statystyki z zastosowaniem STATISTICA PL na przykładach z medycyny, Tom 3. Analizy wielowymiarowe*. Kraków: StatSoft.
37. Steinley, D. (2004). Properties of the hubert-arable adjusted rand index. *Psychological methods*, *9(3),* 386.
38. United Nations (2015). *The 2030 Agenda for Sustainable Development*. Nowy Jork.
39. Trębska, P. (2018). Sytuacja kobiet na europejskim rynku pracy w warunkach zrównoważonego rozwoju. *Nierówności społeczne a wzrost gospodarczy, 55*, 338-347.
40. Walesiak, M. (2011). *Uogólniona miara odległości GDM w statystycznej analizie wielowymiarowej z wykorzystaniem programu R*. Wrocław: UE Publishing House in Wrocław.
41. Ward, J.H. (1963). Hierarchical Grouping to Optimise an objective Functions. *Journal of the American Statistical Association, no. 58.*