Article

Economic Development of the European Union in the Relation of Sustainable Development—Taxonomic Analysis

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Abstract: The purpose of this paper is a multidimensional assessment of the diversification of economic development in EU countries in the context of the progress in the implementation of the concept of sustainable development in 2014 and 2019. The issues discussed in this article are topical and important, given that the spatial disparity of economic development in the EU has never been so pronounced as it is today. While there is a wealth of studies on economic development in the literature, research on the comprehensive approach to this problem in the relation of sustainable development appears to be rather scarce. The article emphasizes the role of energy in economic growth. Authors used taxonomic measures. They were constructed on the basis of selected methods of multidimensional comparative analysis. By using the Hellwig method and the TOPSIS method, taxonomic measures were constructed, and linear ordering of the EU countries was carried out. In addition, using the so-called threshold method, the clustering of EU countries was carried out. The analysis involved 27 EU countries. The conducted research revealed significant disproportions between the respective EU countries in terms of the level of economic development in the relation of implementing the concept of sustainable development. It seems justified to take action aimed at eliminating the differences between the countries in the analyzed aspect. It is necessary both to intensify efforts at the level of individual Member States and the EU, oriented towards pro-development activities.

Keywords: economic development; sustainable development; energy; multidimensional comparative analysis; EU countries

1. Introduction

Sustainable development is the overarching goal of the European Union (EU), leading towards economic growth, EU citizens' prosperity, and a higher quality of life for present and future generations [1]. The concept of "sustainable development" is proposed by the Brundtland Commission as a "development that meets the needs of the present, but does not jeopardize the ability of future generations to meet their personal needs" [2]. American economist Donella Meadows (as cited in [3]) notes that the world population is doubling approximately every 40–50 years. At the same time, however, the planet, which provides the energy and materials necessary for the functioning of society and economy, cannot increase its resources. In addition, along with the world's growing population and economic development, the global demand for increasingly scarce energy resources continues to rise, and the global economy is threatened by a growing energy deficit and hence also a significant degradation of the natural environment. The concept of sustainable development, which is the basis of ecological economics, assumes that subsequent economic development can only take place within the limits of nature's tolerance. Thus, attention is drawn to the need for selective economic development, marked by an increased role of some sectors (such as renewable energies or R&D) and a diminished role of others (such as those relying on conventional energy sources), improving efficiency, coherence of

operation, and sufficiency of natural resources, including energy [4]. Broadly, it means a development that takes into account economic, social, and environmental aspects, balancing out their importance in a sustainable way. Hence, a responsible and forward-looking energy policy is an important driver of sustainable development, with access to energy sources being one of the prerequisites of economic development [5–13]. The conditions of access to energy, the cost of obtaining it, and the lack of an energy substitute are factors influencing sustainable development and the rate of economic growth. The implementation of sustainable development in the area of energy is expected, among other outcomes, to increase the efficiency of energy consumption, rational management of natural resources, and reduction of waste, including CO_2 emissions. Long-term forecasts of global energy consumption indicate the possibility of a 2.5–3-fold increase in energy consumption in 2050 compared to 2010 [14]. Therefore, the effective management of energy carriers in the economy is of pivotal importance for sustainable development, and the significance of energy as a factor limiting sustainable development is bound to increase.

The EU has for years been engaged in sustainable activities and has made attempts to outline a European strategy for sustainable development. The strategy is based on measures to ensure energy security and improve economic competitiveness. It is assumed that the objectives of the EU energy strategy will be met while ensuring safe and uninterrupted energy supplies at an acceptable price and in an environmentally friendly manner. The EU energy policy focuses mainly on three areas: renewable energy; reducing harmful pollutant emissions, in particular CO_2; and increasing energy efficiency [15]. If implemented successfully, the policy should propel the EU towards lower consumption, and a safer and more competitive economy based on sustainable energy. Meeting these targets is expected to contribute to transforming Europe into a more efficient economy marked by low CO_2 emissions. In turn, it will usher in a new industrial revolution, quickening the transition to low-CO_2 economic development, and in the future, to an increase in the production and consumption of low-emission locally sourced energy.

In relation to energy management, sustainable development consists of the optimal use of energy resources to ensure sustainable economic and social development in line with environmental requirements. A sustainable energy policy primarily includes the principle of rational use of energy, which helps improve energy efficiency, protect the environment, and increase energy security [16]. It envisages integrated energy action for both energy supply and demand, using state-of-the-art technologies that favor the environment and improved quality of life [17].

The aim of this presented study is a multidimensional assessment of the diversification of economic development in EU countries in the context of the progress in the implementation of the concept of sustainable development in 2014 and 2019. The issues discussed in this article are topical and important, given that the spatial disparity of economic development in the EU has never been so pronounced as it is today. While there is a wealth of studies on economic development in the literature, research on the comprehensive approach to this problem in the relation of sustainable development appears to be rather scarce.

The problem area of sustainable development has been met with great interest among researchers, as evidenced by the constantly growing number of scientific papers devoted to various issues related to this subject [18–28]. An overall positive approach to this concept of development tends to be predominant in the literature, although this is not to say voices of criticism are not there, especially as the very definition of sustainable development is controversial. Despite many attempts having been made over the years, scholars have so far been unable to work out a clear interpretation of this term [29–32]. Sustainable development is not a uniform strictly demarcated category, but rather a fluid concept that changes its scope and reflects different value systems over time and in space. Nevertheless, despite its ambiguity, certain common elements can still be identified, such as a long-term horizon in relation to the principles of environmental protection, careful management

of natural resources, and precautionary measures towards natural capital guided by the principles of justice [33].

The multidimensional nature of sustainable development, which translates into different ways of interpreting this concept, the lack of an unambiguous definition and the complexity of the problem area that it encompasses, make it difficult to gauge and compare relevant research findings. Therefore, the assessment of the progress of EU countries in implementing the economic governance in the context of sustainable development requires the selection of an appropriate set of indicators. For a long time, there has been a discussion in the literature on the measurement of sustainable development and the choice of commonly accepted indicators [34–47] by identifying a number of prerequisites in relation to the adopted variables. These should be relevant for the purpose of the study and consistent with the adopted definition of sustainability, measurable, define all areas of sustainability, independent of each other, and non-duplicating in terms of the conveyed information, as well as being reliable and easily accessible, up to date, and regularly updated [48]. The use of a set of statistical benchmarks allows for a comprehensive coverage of numerous thematic areas that make up the concept of sustainable development in the context of national and regional policy, while ensuring the possibility of their in-depth analysis in selected topics. The sets of indicators enable not only the assessment of the current state, but also the formulation of measurable goals, monitoring of the changes taking place, and evaluation of the effects of the decisions and actions being made along the way [49]. The following criteria were used in selecting indicators for this economic-dimension study: presence on the list of indicators for monitoring the implementation of the EU Sustainable Development Strategy, international comparability, data availability, and credibility of the data source.

Two annual reports were analyzed in the research procedure for comparative purposes: one of 2014 (first year when the data is available for all 27 EU countries, after including Croatia) and the other of 2019 (for which the latest values of the analyzed indicators are available for all 27 EU countries). The nature of the problem favored the choice of the following research methods: literature and strategic documents analysis, descriptive statistics, and multivariate analysis.

Economic development is a complex category due to this fact the authors used taxonomic measures and constructed them based on the selected methods of multivariate comparative analysis. The taxonomic measures were constructed on the basis of the suggested partial indicators, which were divided into the five thematic areas: (1) economy, (2) production and transportation patterns, (3) innovation, (4) energy patterns, and (5) employment. The indicators describing the individual areas provide an overview of the EU's progress towards sustainable development in terms of economic goals, taking into account energy concerns.

In our opinion, these indicators best reflect the economic development and the idea of sustainable development in the EU. Applying taxonomic measures, which replaced the description of the studied objects (EU countries) with the use of a number of partial indicators with a description using one aggregate quantity, made it possible to measure the multidimensional phenomenon of economic development within respective EU countries, and also allowed for linear ordering of the examined objects (EU countries).

The first part of the article focuses on issues related to defining and measuring economic development presented in the literature. The second part presents the methodology and characterizes the results of the research. The authors used the TOPSIS method and the Hellwig method. They constructed taxonomic measures and performed linear ordering of the EU countries. Application of the two taxonomic methods is some kind of "confirmatory analysis" and allows the results to be compared. In addition, using the so-called threshold method, the clustering of EU countries was carried out. The analysis involved 27 EU countries. The selection of partial indicators was made on the basis of the following criteria: content-related, statistical, and formal (mainly relevance, completeness, and availability for all 27 EU countries in 2014 and 2019).

2. Assessing the Level of Economic Development: Review of the Literature

Economic development is one of the pillars of sustainable development, spanning three main areas: economic, meaning the pursuit of a sustainable economy; social, meaning protection of public health, education, and social integration; and environmental, meaning an emphasis on the protection of the environment and natural resources [50]. Let us note that economic growth, social progress, and environmental order should be viewed as interdependent phenomena, which implies the need for a synergistic problem-solving approach on the path towards sustainable development [51,52]. Economic development is a long-term process that takes into account changes in the economy. It includes quantitative changes in basic macroeconomic values and qualitative changes in the socio-economic system as well as the organization of society [53,54] The quantitative dimension is equated with the concept of growth in relation to production, employment, investment, the size of functioning capital, income, consumption, exports and housing resources, and other economic quantities characterizing the economy from the quantitative point of view. Energy is a factor in economic growth, and one seen by many governments as a strategic good [55]. The development of the energy sector brings tangible economic effects, as the increase in electricity prices for end users is counterproductive to the economy and curbs the activity of energy-intensive industries [56]. The use of renewable energy resources is one of the essential components of sustainable development, marked by clear economic, environmental, and social benefits. The EU's 2020 assumption was to achieve 20% of the final gross energy consumption from renewable sources [57]. The implementation of EU provisions in the area of energy efficiency is to improve energy security, counteract climate change, and should also have a positive impact on the economy through the promotion of market growth, new services, and innovative energy technologies.

From the qualitative perspective, economic development is expressed in transformations in the organization of society and the economy of a structural nature, which include, in particular, technical and technological progress, improvement of the intra-economic system and with the world economy, increase in the qualifications of the workforce, changes in the structure of the economy aimed at its modernization, increase in the level of effectiveness on a micro- and macroeconomic scale, as well as the emergence of new products and improvement of the existing ones. The high economic growth rate requires increased participation in the economy of innovative products and services. The condition for this is to ensure energy security [58].

According to Lange [59], economic development is growth in the productive forces of society. It contributes by increasing the quality of goods and services that satisfy human needs, an increase in wealth and prosperity. An analogous definition of economic development was put forward by Myrdal [60], who assumed that such development meant growth changes in the entire social system, including factors, such as production conditions, productivity and income, quality of life, attitudes towards the way of life, and work. Thus, economic development means changes in the structure of the production potential of the economy, the structure of production and consumption, socio-economic relations, and the system of functioning of the economy [61]. In contemporary terms, economic development is understood as a process of positive changes in the production and redistribution of goods and services, and their exchange and use for consumption purposes, increasing the economic potential of the state [62]. The study provides evidence of long-term and causal relationships between energy consumption and economic growth. Limited access to modern energy services could impede economic growth and compromise the development prospects of countries [63].

In the literature, economic development is generally identified as a long-term and multifaceted process [64,65] relating to transformations not only in the entire economic system, but also within the social realm [66], and even in the natural environment [67]. It concerns targeted and lasting changes taking place in the field of all economic activity, as well as in the social, socio-productive, and political relations. The utilization of renewable energy resources is one of the essential components of sustainable development, producing

tangible economic, environmental, and social effects. Growing the share of electricity from renewable energy sources in the internal electricity market has become an important objective of the European Union [56].

In the theory of economics, apart from the concept of economic development, there is also the definition of economic growth. The terms development and economic growth are clearly distinguished [68]. Growth is a quantitative category, understood only as multiplication, increasing the number, while development denotes structural changes [69]. Economic development, as a broader concept, includes economic growth, which presents quantitative changes in management and all kinds of qualitative and structural changes resulting from the progress of civilization [53]. Economic development is defined as the process of transition from a specific state to a more complex or advanced form, while economic growth is defined as the increasing capacity of a given society to produce goods and services that meet human needs. Economic development is understood as the process of transformation of economies with low national income into modern economies, and economic growth means the process of increasing national wealth over time and refers only to the measurable sphere of the economy (after [70,71]). In the literature on the subject, the dominant view is that development is impossible without economic growth [72].

The traditional approach to the factors of economic development most often includes property (capital) resources, natural environment, and demographic resources, which create more or less favorable conditions for the location of various economic activities. Systemic changes, the transformation of the economy, as well as scientific and technological progress have resulted in completely new conditions for economic development. In addition to traditional factors, there are the so-called modern determinants of development, such as economic potential, including the structure of the economy and its ability to transform, as well as social potential, which emphasizes the importance of social predispositions to progress and innovation, and the efficiency of the economic system [73].

Knowledge about the nature of development changes is necessary both to describe the current state of the area under scrutiny (diagnostic utility) as well as to make economic decisions (prognostic utility), both in the micro- and macroeconomic dimension. Identification of the nature of economic changes in a given specific area requires that they are measured. Economic development is a measurable category, but due to the complex nature of the phenomenon, it cannot be measured directly [74]. Economic development at the country level can be measured with both individual and aggregated indicators. The problem of measuring the level of economic development is widely discussed in the literature [75–81]. The effect of this is a large diversity in the methods of its measurement and the list of measures used in international comparative studies. Oftentimes, the discussion on this topic focuses not on the question of the best measure of measures, but on the determination of a synthetic measure. In many studies, the amount of gross domestic product (GDP) is adopted as such a measure. The use of GDP (including GDP per capita) as a synthetic measure of the level of economic development raises many reservations, e.g., due to the fact that the production of various goods and services, including the redundant or harmful ones, is included in GDP, and the differences in the distribution of income within the analyzed countries is ignored [82–86]. However, despite the fact that GDP has many disadvantages, it is still frequently used in assessing the level of economic development. It is assumed that the task of GDP is not to accurately measure long-term economic and social progress, including the ability of a given society to solve problems related to, inter alia, climate change, resource efficiency, and social integration [63].

The reservations about the measures of the level of development based on GDP led to the construction of more complex measures, using certain sets of indicators and an algorithm for combining them into one synthetic measure. In an attempt to eliminate the disadvantages of traditional measures based on the system of national accounts, efforts were made to modify them to take into account the qualitative aspects of the standard of living. Modified national accounts provide a bridge between conventional measures of economic development and indicators of sustainable development. Thus, economic

development can also be measured with indices describing economic welfare and with indicators related to the category of sustainable development. It should be emphasized that the inclusion of the concept of sustainable development in the construction of the synthetic measure means that it should include additional categories, such as social and environmental order (more in: [51,52,87,88]). Access to modern energy is believed to be a prerequisite for sustainable development, poverty alleviation, and the achievement of the Millennium Development Goals [12]. The most famous measures used to compare economic development are the Measure of Economic Welfare, AnNet National Welfare, Index of Sustainable Economic Welfare, Net National Welfare, Index of the Economic Aspects Welfare, Index of Economic Freedom, or Genuine Progress Indicator (after [70]).

However, the literature often indicates that the modified national accounts are also burdened with various problems. Therefore, more and more often, national accounts are replaced with multifaceted measures that take into account various qualitative dimensions of economic development. Examples of such measures include the Geneva method or the Human Development Index. These measures are called synthetic indices or taxonomic measures. The greatest difficulty in constructing these measures is determining the elements that are to be included in them and assigning them an appropriate rank. A common complaint against taxonomic measures of economic development is that they devote too much attention to the qualitative components of prosperity, while overlooking its quantitative dimension. Therefore, the construction of appropriate synthetic indicators remains an open research problem, and the existing indicators should be verified and updated, taking into account new concepts of assessing the level of economic development, statistical data resources, and experiments with the use of existing indicators.

3. Materials and Methods

Economic development is a complex and multidimensional process. Of course, many different indicators can be used to evaluate it. However, the problem of correct assessment appears when some of the indicators point to positive changes, while others to negative ones. Therefore, in this study, the methods of multivariate statistics were used, which allow for the determination of a taxonomic index that replaces a set of many indicators with one aggregate index. The literature presents many different methods of constructing taxonomic indicators, which can be divided into two groups: (1) non-standard (model-free) methods, and (2) standard (model-driven) methods. In the former, the synthetic index is determined mainly by operating on the normalized values of partial indexes. In the latter, a reference (model) object is determined, against which, when calculating taxonomic distances, the distance for all tested objects is calculated.

In this study, taxonomic measures were used, construed on the basis of the two historically oldest methods of linear ordering, namely Hellwig's method and the TOPSIS procedure.

Economic development is a complex category. Therefore, it was decided that taxonomic measures would be used in this study, the two historically oldest methods of linear ordering, i.e., the Hellwig method and the TOPSIS method. Both methods are exemplary but have been developed in two different research areas. The first method was put forward by Hellwig in the field of economics in 1968 ("measure of economic development") [89]. The other method was suggested by Hwang and Yoon based on the decision theory in 1981 (TOPSIS) [90]. Even though both methods are exemplary, Hellwig's method uses as the reference point a pattern, while Hwang and Yoon's method uses a pattern and an anti-pattern. The normalization of partial indicators differs in both methods: standardization in Hellwig's, and zero-unitization in Hwang and Yoon's. The analytical form of the aggregation function is also different, where the obtained values of the synthetic measure are generally in the range [0; 1] in Hellwig's method, and in the range [0; 1] in Hwang and Yoon's. The simultaneous use of different reference methods is a kind of "confirmatory analysis" and enables a comparison of the results. The calculations were performed using Excel.

The procedure of constructing taxonomic measures consisted of several stages.

Stage 1: Determination of a set of partial indicators. Using the substantive and formal criteria, a set of 28 partial indicators was determined (the aspects indicated in the EU Sustainable Development Strategy as well as the significance of the partial indicators and their availability were taken into account). The partial indicators were divided into five thematic areas: economy, production and transportation patterns, innovation, energy patterns, and employment (Table 1). The presented thematic areas were selected based on the assumptions and goals concerning the challenges of sustainable development set out in the EU strategic documents, namely: A European Union strategy for sustainable development [91], Europe 2020—A strategy for smart, sustainable, and inclusive growth [92]. The analysis also took into account the documents adopted at the conference in Rio de Janeiro, which was the key event for the implementation of the concept of sustainable development (mainly documents, such as Agenda 21 [93], the Rio Declaration on Environment and Development [94]) and the Post-2015 Development Agenda entitled "Transforming Our World: The 2030 Agenda for Sustainable Development" [95–98]. The resolutions adopted at other similar events also played an important role in the formulation of the five studied areas: The World Summit on Sustainable Development in Johannesburg [99] and the Rio +20 Earth Summit [100]. The following criteria were used when selecting indicators for individual thematic areas:

- The existence of a substantive relationship (whether the indicator reflects economic development and the idea of sustainable development);
- International comparability;
- Data availability;
- Data source credibility.

Since the validity of weighing indicators relating to spatial data has been questioned by several authors, the assignment of weight coefficients to partial indicators was abandoned. This solution is supported, among others, by the fact that the indicators that were not selected would be given zero weights by default [101,102].

Stage 2: Evaluating the discriminant ability of partial indicators and their capacity – the degree of correlation with other indicators. The research eliminated those indicators for which the value of the coefficient of variation was lower than the arbitrarily set critical threshold value of this coefficient ($r* = 15\%$) were eliminated. Therefore, the following indicators were excluded from the research: X20, X21, and X23. Then, for each subject area, an analysis of the Persona correlation matrix was performed. From each thematic area, one of the indicators for which the correlation coefficient exceeded the threshold value of $r* = 0.7$ was eliminated (two highly correlated indicators provide similar information, therefore it is justified to eliminate one of them). In this way, from the set of indicators describing the indicated thematic areas of economic development, the following indicators were eliminated: X2, X12, and X13.

Stage 3: Determining the nature of the indicators according to the way they affect economic development, i.e., the division of indicators into stimulants, destimulants, and nominants [89,103]. On the basis of the substantive analysis, the nature of the indicators was determined, including stimulants (X1, X3, X5, X6, X7, X9, X10, X11, X14, X15, X16, X18, X19, X20, X25, X26) and destimulants (X4, X18, X24, X25, X28). None of the indicators were nominative. The destimulants were converted into stimulants:

$$x_{ij}^S = -x_{ij}^D \tag{1}$$

where:
x_{ij}^S—value of the *j*-th destimulant variable in the *i*-th object (EU country) converted into a stimulant;
x_{ij}^D—value of the *j*-th destimulant variable in the *i*-th object (EU country).

Table 1. Partial indicators (source: own study based on Eurostat data).

Symbol	Variable	Unit of Measure
	Area 1—Economy	
X1	Real GDP per capita growth	Percentage change on previous year
X2	Real GDP growth	Percentage change on previous year
X3	Investment rate	Percentage of gross domestic product (GDP)
X4	General government debt	Percentage of gross domestic product (GDP)
X5	Environmental tax revenues	Percentage of gross domestic product (GDP)
	Area 2—Production and transportation patterns	
X6	Circular material use rate	Percentage of material input for domestic use
X7	Resource productivity and domestic material consumption (DMC)	Purchasing power standard (PPS) per kilogram
X8	Area under organic farming	Percentage of total utilized agricultural area
X9	Share of rail and inland waterways in total freight transport	Percentage
X10	Share of collective transport modes in total passenger transport	Percentage of total inland passenger-km
X11	Volume of freight transport relative to GDP	Index, 2010 = 100
	Area 3—Innovation	
X12	Human resources in science and technology (HRST)	Percentage of active population
X13	R&D personnel	Percentage of active population—numerator in full-time equivalent (FTE).
X14	Gross domestic expenditure on R&D	Percentage of gross domestic product (GDP)
X15	Government support to agricultural research and development	Euro per inhabitant
X16	Patent applications to the European Patent Office	Per million inhabitants
	Area 4—Energy patterns	
X17	Energy productivity	Purchasing power standard (PPS) per kilogram of oil equivalent
X18	Primary energy consumption	Tons of oil equivalent (TOE) per capita
X19	Share of renewable energy in gross final energy consumption	Percentage of the gross final energy consumption
X20	Greenhouse gas emissions intensity of energy consumption	Index, 2000 = 100
X21	Average CO_2 emissions per km from new passenger cars	g CO_2 per km
X22	Renewable energy sources in transport	Percentage
	Area 5—Employment	
X23	Employment rate	Percentage of population aged 20 to 64
X24	Young people neither in employment nor in education and training	Percentage of population aged 15 to 29
X25	Labor cost index	Percentage change on previous period
X26	Nominal labor productivity per person	Percentage of EU27 total, current prices
X27	Overall employment growth	The percentage change on previous period (based on persons)
X28	Unemployment rate	Percentage of active population

Stage 4: Normalization of indicators. Two methods of normalization of indicators were used: standardization (Hellwig's method) and zero unitization (TOPSIS method) [104]:

- Standardization:

$$z_{ij} = \frac{x_{ij} - \overline{x}_j}{S_j} \qquad (2)$$

where:

z_{ij}—normalized values of the *j*-th variable in the i-th object (EU country);
x_{ij}—value of the *j*-th variable in the *i*-th object (EU country);
S_j—standard deviation.

- Zero unitization:

$$z_{ij} = \frac{x_{ij} - \min\limits_{i} x_{ij}}{\max\limits_{i} x_{ij} - \min\limits_{i} x_{ij}} \tag{3}$$

where:

$\min\limits_{i} x_{ij}$—minimum of the *j*-th variable;

$\max\limits_{i} x_{ij}$—maximum of the *j*-th variable.

Stage 5: Calculation of the taxonomic measures and preparation of rankings of EU countries. For the respective methods, this stage was as follows:

- Hellwig's method

1. The coordinates of the pattern and the distances of individual EU countries from the pattern were determined (for the stimulant indicators):

Pattern coordinates:

$$z_{0j} = \max_i\{z_{ij}\} \tag{4}$$

Distance of objects from the pattern:

$$d_{i0} = \sqrt{\frac{1}{n}\sum_{i=1}^{m}(z_{ij} - z_{0j})2} \tag{5}$$

2. The values of the synthetic variable were determined:

$$s_i = 1 - \frac{d_{i0}}{d_0} \tag{6}$$

$$d_0 = \bar{d}_0 + 2S_d \tag{7}$$

$$\bar{d} = \frac{1}{n}\sum_{i=1}^{n} d_{i0} \tag{8}$$

$$S_d = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(d_{i0} - \bar{d}_0\right)^2} \tag{9}$$

where:

in general $s_i \in [0;1]$;

$\max_i\{s_i\}$ − best item;

$\min_i\{s_i\}$ − worst item.

- TOPSIS method

1. The coordinates of the pattern and the anti-pattern as well as the distances of the objects (EU countries) from the pattern and anti-pattern (for the stimulants indicators) were determined:

Pattern coordinates:

$$z_{0j}^{+} = \max_i\{z_{ij}\} \tag{10}$$

Anti-pattern coordinates:

$$z_{0j}^{-} = \min_i\{z_{ij}\} \tag{11}$$

Distance of objects from the pattern:

$$d_{i0}^{+} = \sqrt{\sum_{j=1}^{m}\left(z_{ij} - z_{0j}^{+}\right)2} \tag{12}$$

Distance of objects from the anti-pattern:

$$d_{i0}^- = \sqrt{\sum_{j=1}^{m} \left(z_{ij} - z_{0j}^- \right) 2}$$

(13)

2. The values of the synthetic variable were determined:

$$s_i = \frac{d_{i0}^-}{d_{i0}^+ + d_{i0}^-}$$

(14)

where:

in general $s_i \in [0; 1]$;
$\max_i\{s_i\}$ − best item;
$\min_i\{s_i\}$ − worst item.

In order to test the convergence of the results obtained using the two methods, the value of Spearman's rank correlation coefficients between taxonomic measures was calculated. In addition, the presented study also grouped EU countries. By using the so-called threshold method [40], four clusters of countries were distinguished:

Cluster 1 (countries with a very high level of development):

$$s_i \geq \overline{s_i} + S_{s_i}$$

(15)

Cluster 2 (countries with a high level of development):

$$\overline{s_i} + S_{s_i} > s_i \geq \overline{s_i}$$

(16)

Cluster 3 (countries with an average level of development):

$$\overline{s_i} > s_i \geq \overline{s_i} - S_{s_i}$$

(17)

Cluster 4 (countries with a low level of development):

$$s_i < \overline{s_i} - S_{s_i}$$

(18)

where:

s_i—synthetic variable;
$\overline{s_i}$—arithmetic mean of the synthetic variable;
S_{s_i}—standard deviation of the synthetic variable.

4. Research Results and Discussion

The research shows that in the EU, there is a different level of economic development in relation to the concept of sustainable development. In 2014, the average value of the synthetic measure calculated according to Hellwig's method was 0.1560. The highest level of this measure was noted in Austria (0.2885) and Sweden (0.2842) and Denmark (0.2824), and the lowest in Greece (−0.0319), Bulgaria (0.0185), and Cyprus (0.0286). The value of the synthetic measure for the countries with the highest values was therefore several times higher than the measure for the countries with the lowest values. A similar situation also took place in 2019. The significant diversification of the economic development of EU countries is also confirmed by the high coefficient of variation, calculated by the Hellwig method in both 2014 and 2019, which amounted to over 51%.

The differences in the level of economic development in the EU are also indicated by the TOPSIS method, although the differences in the level of the synthetic measure between individual countries are not as large as in the case of the Hellwig method.

From the research conducted, it is also evident that in the EU in 2019, compared to 2014, the average value of the synthetic measure decreased (by approximately 5%), as well

as the maximum and minimum value. A lot of EU countries recorded a decline in the synthetic measure, which indicates unfavorable changes in their economic development in relation to sustainable development. In the case of the Hellwig method, a decrease in the synthetic measure was recorded by as many as 16 countries (increase in 11 countries), while in the case of the TOPSIS method, a decrease was recorded in 17 countries (an increase in 9 countries) (Table 2).

Table 2. The taxonomic measures.

EU Countries	The Hellwig Method		The TOPSIS Method	
	2014	**2019**	**2014**	**2019**
Austria	0.2885	0.2597	0.5250	0.5080
Belgium	0.1932	0.1870	0.4483	0.4576
Bulgaria	0.0185	0.0325	0.3527	0.3897
Croatia	0.1037	0.1385	0.3898	0.4274
Cyprus	0.0286	0.0881	0.3740	0.3632
Czechia	0.1703	0.1394	0.4503	0.4287
Denmark	0.2824	0.2841	0.5283	0.5273
Estonia	0.1564	0.2226	0.4707	0.5063
Finland	0.2259	0.2185	0.5035	0.4726
France	0.2059	0.1776	0.4443	0.4238
Germany	0.2224	0.1940	0.4728	0.4600
Greece	−0.0319	−0.0204	0.3401	0.3592
Hungary	0.1907	0.1266	0.4547	0.4244
Ireland	0.2166	0.2658	0.4880	0.5113
Italy	0.1809	0.1305	0.4505	0.4205
Latvia	0.1397	0.1540	0.4476	0.4517
Lithuania	0.1191	0.0776	0.4183	0.4178
Luxembourg	0.1464	0.1392	0.4759	0.4513
Malta	0.1122	0.1236	0.4257	0.4481
Netherlands	0.2297	0.2458	0.5081	0.5240
Poland	0.1477	0.0747	0.4056	0.4043
Portugal	0.0629	0.0895	0.3746	0.3965
Romania	0.1179	0.0742	0.4264	0.4058
Slovakia	0.1444	0.1028	0.3961	0.3852
Slovenia	0.1552	0.1484	0.4389	0.4326
Spain	0.1018	0.1004	0.3776	0.3700
Sweden	0.2842	0.2476	0.5289	0.5145
MIN	−0.0319	−0.0204	0.3401	0.3592
MAX	0.2885	0.2841	0.5289	0.5273
Average	0.1560	0.1490	0.4414	0.4401
Standard deviation	0.0795	0.0759	0.0535	0.0501

On the basis of the values of taxonomic measures, rankings of the EU countries were created according to the level of economic development in relation to sustainable development. In the case of both methods, the highest positions, both in 2014 and 2019, were held by Austria, Sweden, Denmark, and the Netherlands, which for many years were characterized by the highest level of economic development in relation to sustainable development in the EU. On the other hand, the lowest positions in the ranking of EU countries were occupied by Greece, Bulgaria, and Cyprus. Such low positions of these countries are a consequence of low or very low values of the partial indicators considered (Table 3).

Table 3. Ranking of EU countries.

EU Countries	The Hellwig Method			The TOPSIS Method		
	2014	**2019**	**Rank Change**	**2014**	**2019**	**Rank Change**
Austria	1	3	−2	3	5	−2
Belgium	9	9	0	13	9	+4
Bulgaria	26	26	0	26	23	+3
Croatia	22	15	+7	22	15	+7
Cyprus	25	22	+3	25	26	−1
Czechia	12	13	−1	12	14	−2
Denmark	3	1	+2	2	1	+1
Estonia	13	6	+7	9	6	+3
Finland	5	7	−2	5	7	−2
France	8	10	−2	15	17	−2
Germany	6	8	−2	8	8	0
Greece	27	27	0	27	27	0
Hungary	10	17	−7	10	16	−6
Ireland	7	2	+5	6	4	+2
Italy	11	16	−5	11	18	−7
Latvia	18	11	+7	14	10	+4
Lithuania	19	23	−4	19	19	0
Luxembourg	16	14	+2	7	11	−4
Malta	21	18	+3	18	12	+6
Netherlands	4	5	−1	4	2	+2
Poland	15	24	−9	20	21	−1
Portugal	24	21	+3	24	22	+2
Romania	20	25	−5	17	20	−3
Slovakia	17	19	−2	21	24	−3
Slovenia	14	12	+2	16	13	+3
Spain	23	20	+3	23	25	−2
Sweden	2	4	−2	1	3	−2

In the respective years, no significant differences were observed between the positions of individual countries in the rankings obtained based on the methods of ordering applied. The vast majority of countries were ranked similarly in both methods used. However, the greatest doubts are raised by the results obtained for the following countries: France (the difference between the rankings is seven positions), Luxembourg (in 2014, the difference between the rankings was nine positions; in 2019, compared to 2014, the position improved according to the Hellwig method, and the position deteriorated according to the TOPSIS method), and Poland (in 2019, compared to 2014, according to the Hellwig method, the position deteriorated by nine positions, and according to the TOPSIS method, the position deteriorated by one position). Moreover, in the case of Cyprus and Spain, according to the Hellwig method, the position of countries improved, and according to the TOPSIS method, it deteriorated (Table 3). Therefore, in order to test the convergence of the results obtained with the TOPSIS method and Hellwig method, the values of Spearman's rank correlation coefficients between them were appointed. Despite the doubts indicated above, in the analyzed years, the ratios were very high and amounted to 0.9231 (2014) and 0.9249 (2019), respectively. The critical value rank correlation coefficient of the Spearman (significance level of $\alpha = 0.05$ and for 27 observations) amounts to 0.3827, hence it can be appointed that there is a statistically significant convergence setting in the order of the EU countries between the individual comparisons.

Another analyzed issue was the clustering of EU countries in terms of a similar level of economic development in the relation of the implementation of the concept of sustainable development. The clustering was performed on the basis of the results obtained with the Hellwig's method (Table 3) and TOPSIS method (Table 4). According to the threshold method, the EU countries were divided into four clusters: cluster 1, countries with a very high level of development; cluster 2, countries with a high level of development; cluster 3,

countries with an average level of development; and cluster 4, countries with a low level of development.

Table 4. Classification of EU countries into clusters: Hellwig's method.

Cluster	Level of Development	Clustering Rule	EU Countries
2014			
I	very high	$z_i \geq 0.2356$	Austria, Denmark, Sweden
II	high	$0.2356 > z_i \geq 0.1560$	Belgium, Czechia, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Netherlands
III	medium	$0.1560 > z_i \geq 0.0765$	Croatia, Latvia, Lithuania, Luxembourg, Malta, Poland, Romania, Slovakia, Slovenia, Spain
IV	low	$z_i < 0.0765$	Bulgaria, Cyprus, Greece, Portugal
2019			
I	very high	$z_i \geq 0.2249$	Austria, Denmark, Ireland, Netherlands, Sweden
II	high	$0.2240 > z_i \geq 0.1490$	Belgium, Estonia, Finland, France, Germany, Latvia
III	medium	$0.1490 > z_i \geq 0.0731$	Croatia, Cyprus, Czechia, Hungary, Italy, Lithuania, Luxembourg, Malta, Poland, Portugal, Romania, Slovakia, Slovenia, Spain
IV	low	$z_i < 0.0731$	Bulgaria, Greece

In the analyzed years (2014, 2019), the clustering results were very similar in both methods used. In relatively few cases, the countries took a different cluster, and it was a difference by one cluster only, i.e., for example, according to the Hellwig method, the country was in cluster I and according to the TOPSIS method in cluster II. There was no case where the difference in the position of the country was two or three clusters, i.e., for example, according to the Hellwig method, the country was in cluster II, and according to the TOPSIS method in cluster IV (Tables 3 and 4). In only a few cases, countries took a different cluster, and this was a difference of only one cluster.

In 2014, according to the Hellwig method, the most numerous clusters were the countries characterized by a high (10 EU countries) and an average level of development (10 EU countries), while the least numerous was the cluster characterized by a very high development (three EU countries). In 2019, however, there was a change, as the most numerous cluster included only countries with an average level of development (14 EU countries), while the least numerous countries belonged to the cluster with a low level of development (two countries) (Table 4, Figure 1).
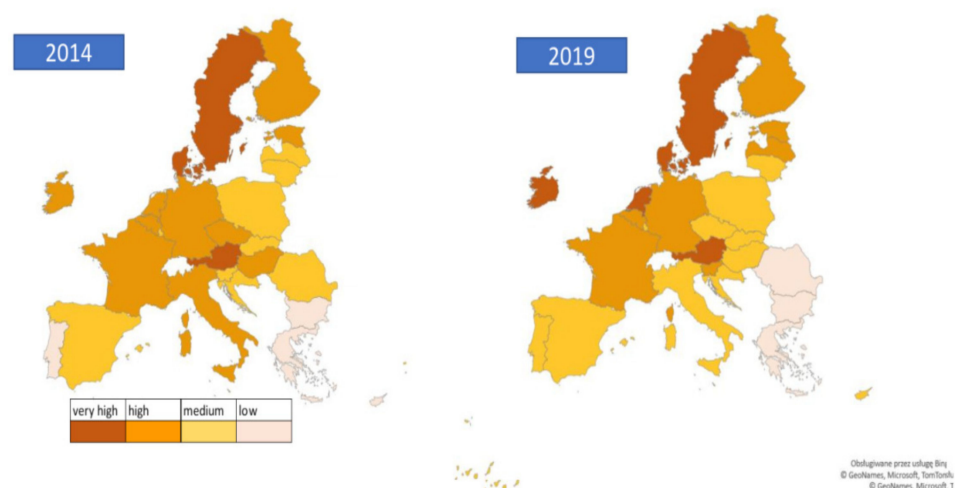

Figure 1. Classification of EU countries into clusters: Hellwig's method.

In 2014, according to the TOPSIS method, the most numerous clusters were the countries characterized by a high level of development (10 EU countries), while the least numerous was the cluster characterized by very high (five EU countries) and low development (five EU countries). In 2019, however, there was a change, as the most numerous cluster included countries with an average level of development (10 EU countries), while the least numerous countries belonged to the cluster with a low level of development (five countries) (Table 5, Figure 2).

Table 5. Classification of EU countries into clusters: TOPSIS method.

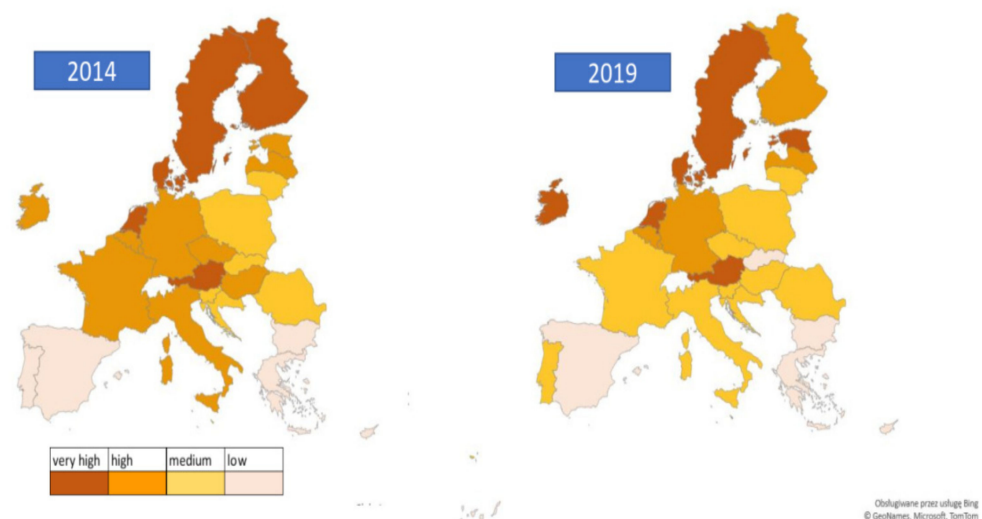| Cluster	Level of Development	Clustering Rule	EU Countries
2014			
I	very high	$z_i \geq 0.4948$	Austria, Denmark, Finland, Netherlands, Sweden
II	high	$0.4948 > z_i \geq 0.4414$	Belgium, Czechia, Estonia, France, Germany, Hungary, Ireland, Italy, Latvia, Luxembourg
III	medium	$0.4414 > z_i \geq 0.3879$	Croatia, Lithuania, Malta, Poland, Romania, Slovakia, Slovenia
IV	low	$z_i < 0.3879$	Bulgaria, Cyprus, Greece, Portugal, Spain
2019			
I	very high	$z_i \geq 0.4902$	Austria, Denmark, Estonia, Ireland, Netherlands, Sweden
II	high	$0.4902 > z_i \geq 0.4401$	Belgium, Finland, Germany, Latvia, Luxembourg, Malta
III	medium	$0.4401 > z_i \geq 0.3899$	Croatia, Czechia, France, Hungary, Italy, Lithuania, Poland, Portugal, Romania, Slovenia
IV	low	$z_i < 0.3899$	Bulgaria, Cyprus, Greece, Slovakia, Spain

Figure 2. Classification of EU countries into clusters: TOPSIS method.

According to the Hellwig method and the TOPSIS method, the following countries: Austria, Denmark, and Sweden, are characterized by a stable very high level of development in both methods used (they belonged to cluster 1 in both 2014 and 2019). In addition, Portugal should be assessed positively, as in 2019, they were in the cluster characterized by a higher level of development compared to 2014. On the other hand, unfavorable changes

in the level of development were noted by the following countries: the Czech Republic, Hungary, and Italy, which in 2019 were in clusters with a lower level of development compared to 2014 (Tables 4 and 5).

5. Conclusions

The study was done in two variants. The first study concerned the evaluation of the diversity of EU countries states in conditions of economic development in relation to the implementation of the sustainable development idea in two years: 2014 and 2019. The indicators describing the individual areas provide an overview of the EU's progress towards sustainable development in terms of economic goals, taking into account energy concerns. The second study adopted the temporal approaches. It evaluated the progress of the EU countries towards economic development in relation to sustainable development in 2019 compared to 2014. The results of the analyses carried out may contribute to the assessment of the effects of the development policy pursued in the EU members so far. On the basis of the presented results, a conclusion can be drawn that positive changes are taking place in many UE countries, bringing them closer to the successful implementation of the paradigm of sustainable development, one of the main priorities of the Europe 2020 Strategy [60].

The article sets out taxonomic measures of economic development in view of the implementation of the sustainable concept by means of the two taxonomic methods on the basis of which the studied countries were ranked. Moreover, as a result of the conducted research, four clusters of countries were created, which are characterized by a similar level of economic development. The conducted analysis proves that in the analyzed years, the countries with the highest level of development were Austria, Sweden, Denmark, and the Netherlands. The following countries received very low ranks: Greece, Bulgaria, and Cyprus.

The conducted research revealed significant disproportions between the respective EU countries in terms of the level of economic development in relation to implementing the concept of sustainable development. It seems justified to take action aimed at eliminating the differences between the countries in the analyzed aspect. It is necessary to both intensify efforts at the level of individual Member States and the EU, oriented towards pro-development activities. It should be mentioned here that the analysis of the research results indicates some negative phenomena, possibly indicating some unfavorable changes in many EU countries:

- In 2019, compared to 2014, the average value of the synthetic measure in the EU decreased (by approximately 5%), as well as the maximum and minimum value; 16 countries saw a decline in the synthetic measure;
- The clustering obtained with the threshold method shows that in 2014, the cluster of countries with a high (Hellwig method, TOPSIS method) and an average level of development (Hellwig method) dominated, while in 2019, the cluster with an average level of development was already dominant.

Research shows that the energy-related situation of individual countries significantly determines economic development, which is clearly differentiated across the EU. The diversity of the energy sector in the EU is the result of both endogenous and exogenous factors. Let us note that the structures of energy production, and thus the energy security of individual countries, are often conditioned by historical considerations, such as the adopted solutions in the field of energy production, as well as practical ones, resulting from the availability of the raw material. In the EU, there are countries with economies that are heavily dependent on fossil fuels (most EU members) but also those with an increasing share of renewable energy sources. The surveyed countries also differ in their approach regarding the shaping of relations with energy-supplying states, especially the Russian Federation. The improvement of the current state of affairs has been adversely affected by the collision of environmental and energy goals. The EU is striving to lead the prime in environmental protection, which means high costs for sector transformation and this may

result in deterioration of the competitive position of both individual Member States and the entire community. The EU is an economy largely propelled by fossil fuels, to which it does not have sufficient access to cover its current and future needs. The dependence of the European economy on fossil fuels means there is a need to look for new suppliers among third countries, which may trigger a strong dependence on new suppliers and therefore a significant impact on economic development. It also means that the achievement of the EU's economic goals depends heavily on the global economic conditions for energy resources and their tariffs. In accordance with the assumptions laid out in the strategic documents, the EU aims to introduce high standards of environmental protection, but its expectations collide with those of the United States, Russia, China, Brazil, and India, which are all major pollutants. While the EU strives for sustainable development, the other countries think about effective economic development and are reluctant to introduce any restrictions that could disrupt their national policies, thus making it necessary to seek an environmental compromise on the international forum [105].

The conducted research is not free from limitations that may affect the obtained results and conclusions drawn. Let us stress that the main barrier for the conducted research was issues related to access to the necessary data.

The research and results obtained as part of this study may constitute material for further analyses using other statistical methods and other partial indicators. They encourage the implementation of similar research at the level of other countries.

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