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Study of spatial uniformity of sustainable development of the European Union before, during and after the economic crisis³

1. INTRODUCTION

Dynamic changes noted on the world markets, which are predominantly connected with economic slowdown coerce the consideration of the uniformity of development of each regions. A particularly interesting area of research in this field is the impact analysis of social and economic development for example on the basis of sustainable development indicators: before, during and after the economic slowdown in 2007–2008. The analyses of that type allow to track changes in individual EU countries, forming a single organism, but they are characterized by differing levels of development, with different resistance to the crisis of 2007–2008 and often completely different social and economic realities.

The basic question we ask, whether it is possible to talk about balancing the socio-economic development in the European Union? Posing such questions is particularly important in the case of such political and economic structures such as European Union. The basic, strategic developmental objectives of the European Union include the aspiration to harmonious development of all of its members, however, it is extremely difficult task as both the statistical data and the operational experience prove. A separate, and extremely important issue is the measuring of homogeneity (heterogeneity) of particular regions of the European Union.

The purpose of the paper is study of spatial uniformity in the field of sustainable development of European Union and geographical regions of Europe ana-

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lyzed by the prism of EU countries located in these regions before, during and after the economic crisis in 2007–2008. In the work to study the spatial differentiation of social and economic development of European Union, on the basis of sustainable development indicators presented by Eurostat, the taxonomic measure of development based on median Weber vector as well vector calculus were used. The previous study by the authors (Bąk, Cheba, 2017) confirmed the existence of significant heterogeneity of spatial development of individual geographical regions of the European Union. Therefore, further research will concentrate on studying the applications of discussed methods will be based on data sustainable development indicators, analyzed separately before, during and after the period of economic slowdown. The results presented in the work will contribute to increasing knowledge about methods testing homogeneity (heterogeneity) of the development in the regional aspect and methods showing the direction of the analyzed changes in the situation of economic crisis.

The paper is organized as follows: the second part describes the methodological issues of the empirical analysis presented in the paper, including indicators and statistical methods description. The following part presents study results which were divided into two topics: results of EU Member States' ranking in the field of sustainable development and uniformity of the balanced development of the European Union. The final part of the article put forward conclusions.

2. METHODOLOGICAL ISSUES OF THE EMPIRICAL ANALYSIS

2.1. Background

The question how to measure the social and economic development is particularly important in the face of growing crises that have economic, political or social origins (Peacock et al., 1988; Rigobon, 2003; Lopez, 2005; Autor et al., 2008; Klenert et al., 2015; Kobayashi, Shirai, 2016; Moomaw et al., 2017). As it has been known for a long time that classical measures of economic development don't reflect well enough the actual development of countries, the measures that describe also the qualitative aspects of their prosperity (including the social and environmental ones) have been sought (Eagle et al., 2010). One of the studies' direction on new economic development measures was the idea of sustainable development which was born in response to the criticism of over-exploitation of natural environment that led to increased global threat of natural disasters (Duran et al., 2015). Information about risks related with excessive use of natural environment had been published in U Thant's report of 1967 (Meadows, 1973). These threats, particularly the ones related with the depletion of natural resources and the degradation of ecosystems are also mentioned in the 1972 Club of Rome report *The Limits to growth* (Berger, Zwirner, 2008). While, the concept of sustainable development was first formulated explicitly during the

Third UNEP Program in 1975, as "(...) such a course of inevitable and desirable economic development that would not materially and irreversibly affect the human environment and would not lead to the degradation of the biosphere and would not undermine the laws of nature, economics and culture" (UN, 1975). Next this concept was presented in 1987 in "Our Common Future", a publication also known as Brundtland Report. The Report was created by the UNO commission established with the intention of developing a global programme of changes in the concept and practice of development. It states that the rapid growth of civilisation, equated to the increased general well-being, leads to overexploitation of natural resources and, in effect, can endanger the global ecosystem. In this report sustainable development was defined as "sustainable development to meet current needs without the risk that future generations will not be able to meet their needs" (WCED, 1987).

The idea of sustainable development is not contradictory to the growth in prosperity. However, the emphasis is on the optimisation of economy with simultaneously minimised consumption of raw materials, energy and water as well as the reduced human environmental impact. Consequently, the principal rule of the sustainable development is the need to address the three pillars: the society, economy and environment (van den Bergh, Hofkes, 1998; Hopwood et al., 2005). Also, this concept points to the need to cross both the institutional and geographical borders in order to coordinate strategies and make proper decisions in the framework of the cooperation of governmental agencies from different countries. It means that it is necessary to look at the current problems faced by the European Union not only from the Union's or individual countries' perspective, but also from the perspective of individual regions that are functionally or geographically related. More than a decade after the first EU enlargement following the accession of the East European countries in 2004, the divisions within the EU, such as distinguishing between the old and new EU Member States, still seem to exist. These divisions are also noticeable when we compare the indices of the EU sustainable development changed before, during and after the economic slowdown in 2007–2008. The European Commission announces the results of monitoring the sustainable development (SD) indices on the biannual basis. Its latest report was published in 2015 (European Union, 2015). The implementation of the EU Sustainable Development Strategy (EU SDS) is monitored by means of the sustainable development indicators (SDI) published by Eurostat. Until recently (the change of the way of SDI presentation according the Agenda 2030 took place on 15.11.2017) the SDIs had a hierarchic structure whose components were divided into three levels. At the top there were 11 Headline Indicators that were intended to give an overall picture of the progress in terms of the key challenges of the EU SDS. The second level was represented by 31 Operational Indicators that related to the operational objectives of the strategy, while on the third, lowest level there were 84 Explanatory Indicators

that illustrated the progress of the actions described in the SDS. In this paper these indicators were used to study the spatial differentiation of sustainable development of European Union countries.

The first step of these studies in the area of sustainable development is usually the analysis of the EU achievements in subsequent years and the assessment of their compliance with the strategic targets. In spite of dynamic changes in individual areas of the EU sustainable development, it is necessary to analyse as well the internal homogeneity of the EU in this aspect. The majority of published studies (Mulder, van den Bergh, 2001; Stefanescu, On, 2012, Boda et al., 2015; Gnimassoun, Mignon, 2015) are based on the assessment if the EU is moving towards the adopted targets. Therefore, the authors concentrate more on assessing the existing level of sustainable development than on the very process of balancing the sustainable development. However, the analysis of internal imbalances among member states proves that developmental differences are significant. The inequalities exist both on the international and regional level. Information obtained from the analyses of individual SD indicators, concerning both individual countries and geographical regions, was used in a study on the SD level in the EU countries in 2004, 2008 and 2014. Apart from the above analyses, the purpose of which was to assess the impact of the 2007/2008 crisis on the sustainable development in individual EU Member States, the collected data helped conduct a spatial analysis of the SD distribution across the EU geographical regions and their countries.

2.2. Objectives, scope and methodology of the study

The objectives of the study were to find an answer to the following questions:

1. Is it possible to talk about balancing the sustainable development in the European Union?
2. How big is the unevenness of sustainable development of particular UE regions, namely:
 - a) How spatially homogeneous (heterogeneous) are those regions?
 - b) Are the identified changes in time homogenous (heterogeneous)?
3. How has the position of the European Union countries in the field of sustainable development changed before, during and after the economic slowdown in 2007–2008?

The analysis of similarities and differences between the European Union countries was based on sustainable development indicators at the EU level (Eurostat, 2017). At the beginning of the study database was set up. In the paper SD indicators presented by Eurostat were used. The original data base included 47 indicators describing 12 themes of the European sustainable development from 2004, 2007 and 2014.

In the next step diagnostic features were selected for the study. The selection criteria is usually divided into two groups: the content related and formal/statistical ones. In the first approach the set of diagnostic features contains such values that, according to the obtained knowledge about the phenomena under study, are the most typical of the compared objects. In the second approach, the selection of features follows a specific formal procedure. The most appropriate is a two-stage selection procedure where both approaches are simultaneously used. After defining and gathering data concerning the initial set of features, proper verification actions are usually performed against two most important criteria:

1. Variability – the features should be diverse, i.e. effectively discriminating the objects.

To assess the variability, a diversity coefficient, calculated from the formula (1), is used:

$$V_j = \frac{S_j}{\bar{x}_j}, \quad (1)$$

where: \bar{x}_j – arithmetic mean of X_j , S_j value – standard deviation of j -th feature X_j , $j = 1, 2, \dots, m$, m – number of features.

Taking into account the former of this criterion, 6 diagnostic features were eliminated from the study, because the coefficients of variation calculated for them were low throughout the whole period of study (at 10% or lower).

2. Correlation – two strongly correlated features carry similar information; therefore one of them is redundant. For this reason, the correlation indicators of all the features should be taken into account, and then, the most suitable verification method should be applied to eliminate features most similar to others. The starting point here is to create a matrix of feature correlations:

$$R = \begin{bmatrix} 1 & r_{12} & \cdots & r_{1m} \\ r_{21} & 1 & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & \cdots & 1 \end{bmatrix}, \quad (2)$$

where: r_{jk} – the Pearson linear correlation coefficient of the j^{th} and k^{th} feature.

In the next step, the matrix of correlations among the features was constructed for every analysed year separately. When examining the similarity of the features by means of the coefficients of variation, it was found that some indicators

were very strongly correlated. Therefore, the formal approach, a parametric method proposed by Hellwig (Nowak, 1990)⁴ was used to select a final set of diagnostic features. The starting point in this method is the matrix of the coefficients of correlation (formula 2) among the potential diagnostic features. The classification criterion is the parameter r^* also called a critical value of the correlation coefficient so that $0 < r^* < 1$. The value of r^* can be chosen at the researcher's discretion or determined in a formal way⁵.

The features from the preliminary list can be similar to one another due to their strong correlation, hence they can form clusters. The clusters are such subsets of features where the least similarity between them is not smaller than r^* . The clusters contain one central features and several satellite ones. A satellite feature of an individual central feature is the one whose similarity to the central feature is not smaller than r^* . The features form a cluster if they consist of one central feature and at least one satellite feature. Then, they are called systemic features. The features that are not attributed to any cluster are called isolated features. The central and isolated features create the so called base configuration of features and they are considered to be diagnostic features. According the proposal of Zeliaś (2000) the final set of data was created by the features (both central and satellite) whose frequency of occurrence was the highest in the whole analyzed period.

To the final set of diagnostic features, which has become a basis for further empirical studies, the following indicators have been selected⁶:

- a) in the area of socio-economic development (3 indicators): young people neither in employment nor in education or training (NEET) (15–24 years), % of the total population in the same age group – (X_{1aDO}); total R&D expenditure, % of GDP – (X_{2aSE}); total unemployment rate, % – (X_{3aDE});
- b) in the area of sustainable consumption and production (2 indicators): generation of waste excluding major mineral wastes, kg per capita – (X_{4bDO}); final energy consumption⁷, 1000 tons of oil equivalent – (X_{5bDE});

⁴ It is the most commonly used method of diagnostic characteristics selection. However, the method is not perfect: it is sensitive to outliers (or asymmetric distribution of variables) and it takes into account only direct relationships of a given characteristic with other ones, ignoring indirect relationships. Improved resistance of the method to outliers can be achieved by replacing in the first step the sum of elements in a column (or a row) of the correlation coefficient matrix by their median. The second fault can be eliminated by means of the matrix inverse method (Nowak, 1990).

⁵ In the paper it was assumed: $r = 0.5$.

⁶ Symbols: a, b, c, d...j – denote the SD theme, S denotes the stimulant, D – the destimulant, while the symbols H, O, E, C – the indicator level: H – headline indicator, O – operational, E – explanatory and C – contextual.

⁷ According to the Eurostat: "this indicator expresses the sum of the energy supplied to the final consumer's door for all energy uses. It is the sum of final energy consumption in industry, transport, households, services, agriculture, etc. Final energy consumption in industry covers the consumption in all industrial sectors with the exception of the "Energy sector".

- c) in the area of social inclusion (4 indicators): early leavers from education and training⁸, % – (X_{6cDO}); tertiary educational attainment, by sex, age group 30–34, % – (X_{7cSO}); long-term unemployment rate – (X_{8cDE}); adult participation in learning (lifelong learning)⁹, % – (X_{9cSE});
- d) in the area of demographic changes (3 indicators): employment rate of older workers, % – (X_{10dSH}); total fertility rate, number of children per woman – (X_{11dSE}); old-age dependency ratio¹⁰, per 1000 persons of working age (15–64) – (X_{12dDC});
- e) in the area of public health (1 indicator): life expectancy at birth of males, years – (X_{13eSH});
- f) in the area of climate change and energy (4 indicators): primary energy consumption¹¹, million TOE (tons of oil equivalent) – (X_{14fDH}); share of renewable energy in gross final energy consumption, % – (X_{15fSO}); electricity generated from renewable sources, % – (X_{16fSE}); share of renewable energy in fuel consumption of transport, % – (X_{17fSE});
- g) in the area of sustainable transport (2 indicators): energy consumption of transport relative to GDP, index (2010–100%) – (X_{18gDH}); energy consumption by transport mode – road transport, 1000 tons of oil equivalent – (X_{19gDE});
- h) in the area of natural resources: no indicators;
- i) in the area of global partnership (1 indicator): CO₂ emissions per inhabitant in the EU and in developing countries, tons – (X_{20iDE});
- j) in the area of good governance (2 indicators): shares of environmental taxes in total tax revenues from taxes and social contributions, % – (X_{21jDO}); level of citizens' confidence in EU institutions (for sub-theme policy coherence and effectiveness), % – (X_{22jSO}).

⁸ According to the Eurostat: „the indicator is defined as the percentage of the population aged 18–24 with at most lower secondary education and who were not in further education or training during the last four weeks preceding the survey. Lower secondary education refers to ISCED (International Standard Classification of Education) 2011 level 0–2 for data from 2014 onwards and to ISCED 1997 level 0–3C short for data up to 2013. The indicator is based on the EU Labour Force Survey”.

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¹⁰ According to the Eurostat: “this indicator is the ratio between the number of persons aged 65 and over (age when they are generally economically inactive) and the number of persons aged between 15 and 64. The value is expressed per 100 persons of working age (15–64)”.

¹¹ According to the Eurostat: by “Primary Energy Consumption” is meant the Gross Inland Consumption excluding all non-energy use of energy carriers (e.g. natural gas used not for combustion but for producing chemicals). This quantity is relevant for measuring the true energy consumption and for comparing it to the Europe 2020 targets. The “Percentage of savings” is calculated using these values of 2005 and its forecast for 2020 targets in Directive 2012/27/EU; the Europe 2020 target is reached when this value reaches the level of 20%”.

The set of diagnostic indicators chosen for the description of the compared objects can contain the variables whose influence on the phenomenon under study has different direction, i.e. stimulants and destimulants. The stimulants are variables whose bigger values indicate a higher level of progress of a given phenomenon, while the destimulants are diagnostic characteristics whose smaller values indicate a higher level of development¹² (Nowak, 1990). The classification of diagnostic characteristics selected for the study into stimulants and destimulants is shown in table 1.

Table 1. DIVISION OF DIAGNOSTIC FEATURES INTO STIMULANTS AND DESTIMULANTS

Stimulants	Destimulants
X _{2a} SE, X _{7c} SO, X _{9c} SE, X _{10d} SH, X _{11d} SE, X _{13e} SH, X _{15f} SO, X _{16f} SE, X _{17f} SE, X _{22j} SO	X _{1a} DO, X _{3a} DE, X _{4b} DO, X _{5b} DE, X _{6c} DO, X _{8c} DE, X _{12d} DC, X _{14f} DH, X _{18g} DH, X _{19g} DE, X _{20i} DE, X _{21j} DO

S o u r c e: own elaboration.

2.3. Description of used mathematical methods

In the work to study the spatial differentiation of development of individual countries in the European Union, on the basis of sustainable development indicators selected to the study¹³, the following methods were used: a) taxonomic measure of development based on median Weber vector and b) vector calculus.

The linear assignment of European countries and defining typological groups of objects was conducted using the method based on the median Weber (1971) vector¹⁴. The positional option of the linear object assignment takes a different normalization formula, in comparison with the classical approach, based on a quotient of the feature value deviation from the proper coordinate of the Weber median and a weighed absolute median deviation, using the Weber median (Lira et al., 2002; Młodak et al., 2016)¹⁰:

$$z_{ij} = \frac{x_{ij} - \theta_{0j}}{1,4826 \cdot m\tilde{a}d(X_j)}, \quad (3)$$

where: $(\theta_{01}, \theta_{02}, \dots, \theta_{0m})$ is the Weber median, $m\tilde{a}d(X_j)$ is the absolute median deviation, in which the distance from the features to the Weber vector is meas-

¹² Sometimes the category of *nominants* is used. In their case the most favourable situation is when they reach a fixed value or number interval.

¹³ The median Weber vector was calculated on the basis of features by transforming destimulants into stimulants on the basis of the following formula: $x'_{ij} = c - x_{ij}$, $i = 1, 2, \dots, n$, $c = 0$.

¹⁴ The median Weber is a multi-dimensional generalization of the classical notion of the median. It is a vector that minimizes the sum of Euclidean distance (Euclidean distance) of the data points representing the considered objects, and therefore is somehow "in the middle" of them, but it is also robust to the presence of outliers (Młodak, 2006, 2014).

ured¹⁵, i.e.: $mad(X_j) = \text{med}_{i=1,2,\dots,n} |x_{ij} - \theta_{0j}|$ ($j = 1, 2, \dots, m$). The synthetic measure μ_i is calculated on the basis of maximum values of normalized features, similarly to the Hellwig (1968) method:

$$\varphi_j = \max_{i=1,2,\dots,n} z_{ij}, \quad (4)$$

according to the following formula:

$$\mu_i = 1 - \frac{d_i}{d_-}, \quad (5)$$

where: $d_- = \text{med}(\mathbf{d}) + 2,5\text{mad}(\mathbf{d})$, where $\mathbf{d} = (d_1, d_2, \dots, d_n)$ is a distance vector calculated using the formula: $d_i = \text{med}_{j=1,2,\dots,m} |z_{ij} - \varphi_j|$, $i = 1, 2, \dots, n$, φ_j – the i -th coordinate of the development pattern vector, which is constituted of the maximum values of the normalized features.

The assignment of objects with a positioning measure is the basis for a division of objects into four classes. The most commonly used grouping method in the positioning scope is called the *three medians method*. It involves indicating a median of vector coordinates $\mu = \mu_1, \mu_2, \dots, \mu_n$, which is denoted $\text{med}(\mu)$, then dividing the population of objects into two groups Ω_k : those, for which the measure values exceed the median (are higher than it – Ω_1) and those, for which the measure values do not exceed the median (are equal or lower than it – Ω_2). Next the indirect medians are defined as: $\text{med}_k(\mu) = \text{med}_{i:\Gamma_i \in \Omega_k}(\mu_i)$, where $k = 1, 2$. This way the following groups of objects are created¹⁶:

- Group I: $\mu_1 > \text{med}_1(\mu)$,
- $\mu_i > \text{med}_1(\mu)$,
- Group II: $\text{med}(\mu) < \mu_i \leq \text{med}_1(\mu)$,
- Group III: $\text{med}_2(\mu) < \mu_i \leq \text{med}(\mu)$,
- Group IV: $\mu_1 \leq \text{med}_2(\mu)$.

The vector calculus was used for the examination of homogeneity of the European Union. The theoretical foundations of vector calculus and the proposal of its implementation with regard to the examination of the level of development of socio-economic objects were presented for instance in the publications by Nermend (2009) and Nermend, Tarczyńska-Łuniewska (2013). This method is characterized by the high level of flexibility, especially in the case of vector

¹⁵ The Weber median was calculated in *R program: l1median* of package: *pcaPP*.

¹⁶ Groups equinumerous are getting when the number of objects in the community is divisible by four.

measure constructed on the basis of scalar product and the arithmetic of the increase proposed by Borawski (2012). It allows to achieve additional information about the uniformity of diagnostic objects included in the analysed object (in the paper considered by the prism of the countries located in European geographical regions).

The vector calculus, depending on the adopted manner of computation of incremental standard deviation and/or the increment of variance might be implemented to research: a) spatial homogeneity of a set of elements located on a bigger spatial unit, for example the homogeneity of EU Member States located over a bigger region and b) time homogeneity of identified changes, for instance over the years. Calculations using synthetic vector measure starts with the designation of so-called ordered twos, which are used for further calculations instead of actual values. These twos form: the mean and the standard deviation and the mean and the variance. In the case of testing the spatial homogeneity of the objects, the values of the analyzed indicators for smaller objects (subobjects, in the work: EU countries) located in the bigger area (in the work: in geographical regions of Europe) are taken into account and mean value (η_j), standard deviation (σ_j) and the variance (σ_j^2) are computed on the basis on following

formulas:

a) mean value (η_j):

$$\eta_j = \frac{\sum_{k=1}^N x_{i,k}}{N}, \quad (6)$$

where: η_j – the mean value of i -th feature for j -th object, N – the number of objects considered in study of spatial homogeneity for j -th object, $x_{i,k}$ – the value of i -th feature for k -th subobject in j -th object,

b) standard deviation (σ_j):

$$\sigma_j = \sqrt{\frac{\sum_{k=1}^N \left(x_{i,k} - \eta_j \right)^2}{N}}, \quad (7)$$

c) variance (σ_j^2):

$$\sigma_{i,j}^2 = \frac{\sum_{k=1}^N \left(x_{i,j,k} - \eta_{i,j} \right)^2}{N}. \quad (8)$$

Mean and standard deviation as well as mean and variance are determined on the basis of the values of the analyzed indicators for smaller objects located on the area of larger objects form ordered twos, and the calculations for them are performed in parallel.

The next step is to determine increases based on which further calculations are conducted. Similar calculations are performed also for a pair consisting of mean value and variance (Nermend, Tarczyńska-Łuniewska, 2013).

$$\left(\Delta \eta_{i,j}, \Delta \sigma_{i,j} \right) = \left(\eta_{i,j} - \eta_{0,j}, \sigma_{i,j} - \sigma_{0,j} \right), \quad (9)$$

$$\left(\Delta \eta_{i,j}, \Delta \sigma_{i,j}^2 \right) = \left(\eta_{i,j} - \eta_{0,j}, \sigma_{i,j}^2 - \sigma_{0,j}^2 \right), \quad (10)$$

where: $\eta_{i,j}$ is the mean i -th variable j -th object, $\sigma_{i,j}$ is standard deviation of i -th variable j -th object, $\eta_{0,j}, \sigma_{0,j}$ are reference points, respectively for the growth of the mean and the standard deviation. Reference points can be arbitrarily chosen and should be identical for all increments of mean values, standard deviations and variances. In practice, in order to simplify a calculation most frequently it is taken as it equals zero. This means that by adding zero to the increment of the mean value, standard deviation or variance we obtain the mean value, standard deviation and variance¹⁷.

In the next stage, the normalization of the designated values pairs (ordered twos) is carried out with the following formula (Nermend, Tarczyńska-Łuniewska 2013):

$$\left(\eta'_{i,j}, \Delta \sigma'_{i,j} \right) = \left(\frac{\Delta \eta_{i,j} - \Delta \bar{\eta}_{i,j}}{\sigma_{\eta_{i,j}}}, \frac{\Delta \sigma_{i,j}}{\sigma_{\sigma_{i,j}}} \right), \quad (11)$$

¹⁷ This is possible until the reference point doesn't change (Nermend, Tarczyńska-Łuniewska, 2013).

and:

$$\left(\eta'_j, \Delta \sigma'_j \right) = \left(\frac{\Delta \eta_j - \Delta \bar{\eta}_j}{\sigma_{\eta_j}}, \frac{\Delta \sigma_j^2}{\sigma_{\eta_j}^2} \right), \quad (12)$$

where: $\Delta \bar{\eta}_j$ – is an mean value of mean values, σ_{η_j} and $\sigma_{\eta_j}^2$ are their standard deviation and variance, respectively.

Prior to the delimitation of synthetic measure a pattern ($\Delta \eta'_i$), which shows the most favorable values of the analyzed feature and anti-pattern ($\Delta \eta'_{aw}$), which illustrates the least favorable values are determined. For this purpose, the value of the first and third quartile is used, which for the stimulant pattern ($\Delta \eta'_i$) assumes the values of the third quartile¹⁸ for stimulant and the first quartile for the destimulant as follows (Nermend, Tarczyńska-Łuniewska, 2013):

$$\Delta \eta'_i = \begin{cases} \Delta_{k_{III}} \eta'_i & \text{for stimulants,} \\ \Delta_{k_I} \eta'_i & \text{for destimulants,} \end{cases}$$

where: $\Delta \eta'_i$ is the value of the i -th normalized variable for the pattern, $\Delta_{k_I} \eta'_i$ is the value of the i -th normalized variable for the first quartile, $\Delta_{k_{III}} \eta'_i$ is the value of the i -th normalized variable for the third quartile.

While, in the case of the anti-pattern ($\Delta \eta'_{aw}$), the procedure is reversed – as its coordinates, the values of the first quartile for the stimulant and the third quartile for the destimulant are assumed. If the pattern is determined and based on quartiles it represents an unreal, idealized object. There is therefore no need to determine the deviation increases for its coordinates. Determination of synthetic vector measure based on the scalar ratio of vectors representing the objects and vectors pattern and anti-pattern is determined on the basis of the formula (Nermend, Tarczyńska-Łuniewska 2013):

$$\Delta m_{s\eta}_j = \frac{\sum_{i=1}^M \left(\Delta \eta'_i - \Delta \eta'_{aw} \right) \left(\Delta \eta'_i - \Delta \eta'_w \right)}{\sum_{i=1}^M \left(\Delta \eta'_i - \Delta \eta'_{aw} \right)^2}. \quad (13)$$

¹⁸ They can also be determined based on the real object.

The next step is to assign the tested objects (in this case: the geographic regions of Europe) to the appropriate classes with following way (Nermend, Tarczyńska-Łuniewska, 2013):

$$cl_j = \begin{cases} 1 & \text{for } \Delta m_{S\eta}_j \geq \overline{\Delta m_S} + \sigma_{\Delta m_S}, \\ 2 & \text{for } \Delta m_{S\eta}_j \geq \overline{\Delta m_S} \quad \wedge \quad \Delta m_{S\eta}_j < \overline{\Delta m_S} + \sigma_{\Delta m_S}, \\ 3 & \text{for } \Delta m_{S\eta}_j \geq \overline{\Delta m_S} - \sigma_{\Delta m_S} \quad \wedge \quad \Delta m_{S\eta}_j < \overline{\Delta m_S}, \\ 4 & \text{for } \Delta m_{S\eta}_j < \overline{\Delta m_S} - \sigma_{\Delta m_S}, \end{cases}$$

where: $\overline{\Delta m_S}$ is the mean value of the mean value increment, $\sigma_{\Delta m_S}$ – is the standard deviation of the mean value increment and cl_j – is class number for the j -th object.

The first class includes the best objects with the highest values of the synthetic vector measures and the fourth class the worst ones with the lowest values.

On the basis of the increments of standard deviations the maximum value of the standard deviation increment is determined, as follows (Nermend, Tarczyńska-Łuniewska 2013):

$$\Delta m_{S\sigma max}_j = \frac{\max_i(\Delta \sigma_i)_j}{\sqrt{\sum_{i=1}^M \left(\Delta \eta_{i_w} - \Delta \eta_{i_{aw}} \right)^2}}. \quad (14)$$

This maximum value of the increments of standard deviation can be interpreted as a measure of the spatial homogeneity ($h_{j\sigma}$) of development. The lower is the value of this measure the greater is homogeneity and the smaller are the differences between the objects and reverse. Next, the ratio of this maximum value of the increments of standard deviation to the width of the class can be estimated. The division into classes according the level of homogeneity of sustainable development and the width of these classes can be carried out in the following way:

$$c_{j\sigma} = \begin{cases} 1 & \text{for } \Delta m_{j\sigma} < p_1 \sigma_{mS}, \\ 2 & \text{for } \Delta m_{j\sigma} \geq p_1 \sigma_{mS} \wedge \Delta m_{j\sigma} < p_2 \sigma_{mS}, \\ 3 & \text{for } \Delta m_{j\sigma} \geq p_2 \sigma_{mS} \wedge \Delta m_{j\sigma} < p_3 \sigma_{mS}, \\ 4 & \text{for } \Delta m_{j\sigma} \geq p_3 \sigma_{mS}, \end{cases}$$

where: $c_{j\sigma}$ is class number for maximum value of standard deviation of j -th object, p_1, p_2, p_3 – scaling factors chosen by the researcher.

3. STUDY RESULTS

Table 2 shows the results of the classification and the typological groups of the EU countries obtained by means of the taxonomic measure of development (formulas 3–5) calculated on the basis of the characteristics of their situation in the area of sustainable development. The positions of individual countries in the obtained rankings were usually different, with the exception of Sweden and Denmark whose positions (the first and the second, respectively) did not change in the years of study. Finland and Italy did not move further than by one or two positions. The greatest leaps were observed in the case of Slovakia which was one second last in the 2004 ranking, then in 2008 jumped 7 positions higher to get to the 7th position in 2014.

Sixteen EU countries did not see any fall in the ranking due to the crisis, while four countries went up in the ranking by at least six positions. The situation in the area of sustainable development in 2008 compared to 2004 deteriorated in 12 countries – the most affected were Hungary (the fall from the 8th to the 22nd position) and France (the fall from the 9th to the 17th position). Cyprus, Ireland, Luxembourg and Spain went down in 2008 by five positions in relation to 2004. Over the decade of 2004–2014 four member states (Cyprus, Greece, Ireland and Portugal) were ranked lower in each of the years 2008 and 2014 in relation to previously studied year. It should be noted that in 2014 only ten EU countries improved their situation in comparison to 2004. A half of them fell in the ranking for 2014 in relation to 2008 with Greece and the Czech Republic going down by 11 and 10 positions, respectively.

Because the position in the ranking of individual EU countries in the years of study is not the same (in some cases the movements in the ranking are considerable), Kendall's tau coefficients were determined in order to assess the conformity of ordering the objects under study (table 3)¹⁹. High values of the coeffi-

¹⁹ Kendall's tau coefficients adopt values from the interval [-1, 1]. The closer their value is to 1, the greater is the conformity of ordering (Stanisz, 2007, p. 313–314).

cients confirm the conformity of linear ordering of countries, despite the differences in positions taken by some objects. The highest correlation coefficient was obtained for the 2004 and 2008 rankings. Sometimes, even one diagnostic feature was decisive for belonging to a particular group, the level of which clearly distinguished countries themselves. Due to this, it was decided to determine the measures ω_j that can be interpreted as the scales defining the relative importance of individual diagnostic features²⁰. These measures were calculated according to the formula (Nowak, 1990, p. 34–35):

$$\omega = \frac{V_j}{\sum_{j=1}^m V_j} \cdot 100\%, \quad (15)$$

where: V_j – classic coefficient of variation calculated for the j -th diagnostic feature.

Table 2. THE EU COUNTRIES SORTED BY THE SUSTAINABLE DEVELOPMENT IN: 2004, 2008 AND 2014

Country	Value of synthetic measure (μ)	Position in the ranking	Group
2004			
Sweden	0.689	1	I
Denmark	0.604	2	
Ireland	0.551	3	
Finland	0.526	4	
Luxembourg	0.428	5	
Slovenia	0.397	6	
Austria	0.350	7	II
Hungary	0.348	8	
France	0.341	9	
Czech Republic	0.322	10	
Latvia	0.300	11	
Lithuania	0.294	12	
Estonia	0.294	13	III
Cyprus	0.289	14	
Portugal	0.285	15	
Belgium	0.250	16	
Greece	0.221	17	
United Kingdom ...	0.216	18	
Netherlands	0.215	19	IV
Germany	0.202	20	
Malta	0.181	21	
Romania	0.177	22	
Spain	0.125	23	
Croatia	0.108	24	
Italy	0.077	25	IV
Bulgaria	0.046	26	
Slovakia	0.013	27	
Poland	-0.076	28	

²⁰ The higher the value of the measure, the greater the importance of the j -th diagnostic feature.

Table 2. THE EU COUNTRIES SORTED BY THE SUSTAINABLE DEVELOPMENT IN: 2004, 2008 AND 2014 (cont.)

Country	Value of synthetic measure (μ)	Position in the ranking	Group
2008			
Sweden	0.716	1	I
Denmark	0.658	2	
Finland	0.526	3	
Austria	0.482	4	
Latvia	0.467	5	
Slovenia	0.434	6	
Czech Republic	0.380	7	
Ireland	0.375	8	II
Lithuania	0.354	9	
Luxembourg	0.342	10	
Estonia	0.320	11	
Romania	0.316	12	
Belgium	0.283	13	
Germany	0.277	14	
Netherlands	0.270	15	III
Portugal	0.262	16	
France	0.253	17	
Greece	0.251	18	
Cyprus	0.247	19	
Slovakia	0.240	20	
United Kingdom	0.222	21	
Hungary	0.210	22	IV
Bulgaria	0.160	23	
Poland	0.157	24	
Malta	0.141	25	
Croatia	0.131	26	
Italy	0.073	27	
Spain	0.003	28	
2014			
Sweden	0.820	1	I
Denmark	0.688	2	
Lithuania	0.633	3	
Luxembourg	0.623	4	
Finland	0.608	5	
Latvia	0.557	6	
Slovakia	0.512	7	
Austria	0.478	8	II
Slovenia	0.469	9	
France	0.465	10	
United Kingdom	0.445	11	
Ireland	0.410	12	
Poland	0.397	13	
Estonia	0.371	14	
Germany	0.339	15	III
Belgium	0.334	16	
Hungary	0.325	17	
Netherlands	0.312	18	
Portugal	0.309	19	
Czech Republic	0.306	20	
Cyprus	0.281	21	
Romania	0.266	22	IV
Croatia	0.219	23	
Bulgaria	0.183	24	
Malta	0.105	25	
Italy	0.074	26	
Spain	0.067	27	
Greece	0.026	28	

Source: own calculations.

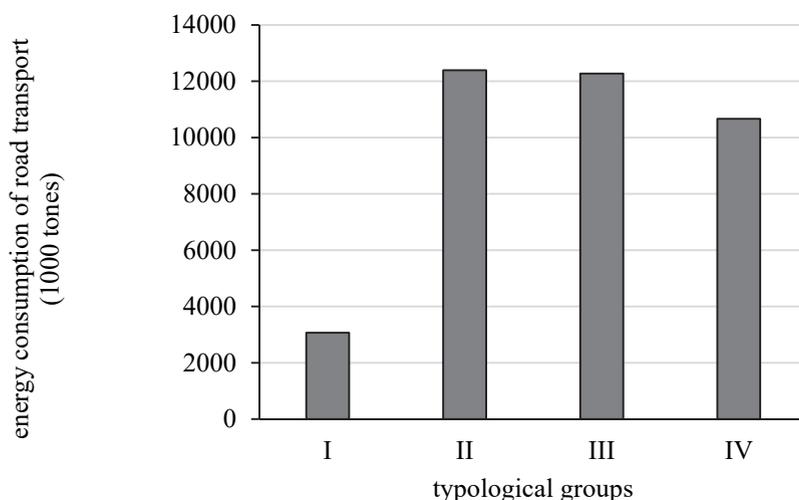
Table 3. KENDALL'S T COEFFICIENTS CALCULATED FOR THE RANKS OF COUNTRIES ACCORDING TO TAXONOMIC MEASURES OF DEVELOPMENT

Year	2004	2008	2014
2004	1.0000	0.6138	0.4815
2008	0.6138	1.0000	0.5714
2014	0.4815	0.5714	1.0000

Source: own calculations.

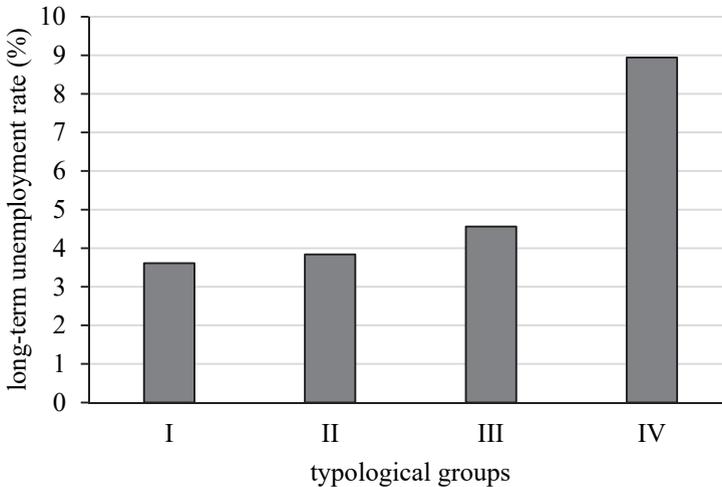
It turned out that in the study of the sustainable development of EU countries based on data from the last analyzed period (2014) the most important are: primary energy consumption (X_{14fDH} – 11.52%), energy consumption of road transport relative to GDP (X_{19gDE} – 11.40%), final energy consumption (X_{5bDE} – 11.30%), long-term unemployment rate (X_{8cDE} – 6.35%), share of renewable energy in gross final energy consumption (X_{15fSO} – 6.20%). These five diagnostic features were characterized by the highest variability in the set of attributes accepted for testing, their share exceeded 46% of the total value of the sum of variability coefficients and therefore they significantly influenced the classification of objects (EU Member States). In order to show the differences in the level of listed characteristics in individual groups, average values in groups were calculated and presented in figures 1–2.

Figure 1. Average energy consumption of road transport, 1000 tons of oil equivalent in typological groups



Source: own elaboration.

Figure 2. Average longterm unemployment rate in typological groups



Source: own elaboration.

In the first group there were seven countries for which the mean values of diagnostic features were definitely higher than the EU mean in the case of stimulants and lower in the case of destimulants. The objects from this group were mainly characterized by low final energy consumption, high share of energy from renewable sources in total energy, low long-term unemployment rate, high level of education (low participation of early school leavers and high share of people continuing education) and higher compared to the average EU citizens' confidence. The priority for the classification of countries in the second group was mainly high expenditure on R&D, good level of education (low share of early school leavers and high share of people with the third level of education) and high level of primary energy consumption. Objects that were classified in the third group were characterized by similar average values of the analyzed diagnostic features in comparison with the second group. However, the lower rating of the third group was the result of the higher level of the total unemployment rate, long-term unemployment rate and the lowest among all groups, the average value for the share of energy from renewable sources in total energy. In the worst situation in terms of sustainable development were EU countries classified into the fourth group characterized by unfavorable values of the majority of diagnostic features accepted for study²¹.

²¹ A similar analysis of typological groups can be made in the years 2008–2013. While examining the importance of diagnostic features according to the formula 15, it was also noticed that in the study of the sustainable development of the EU countries the same features that differentiated objects in 2014 were of the greatest importance.

The next stage of the study was the analysis of spatial homogeneity of the EU countries located in geographical regions of Europe. In this case the results for EU countries located in 4 following geographical regions of Europe were analysed:

- a) Western Europe (Austria, Belgium, France, Germany, Luxembourg, the Netherlands),
- b) Northern Europe (Denmark, Estonia, Finland, Ireland, Latvia, Lithuania, Sweden, the United Kingdom),
- c) Southern Europe (Cyprus, Croatia, Greece, Italy, Malta, Portugal, Slovenia, Spain),
- d) Eastern Europe (Bulgaria, the Czech Republic, Hungary, Poland, Romania, Slovakia).

The analysis results are presented in table 4 which shows both the ordering of the regions according to the level of development of the average country located in these regions (according the formula 13) and the results of the spatial homogeneity of sustainable development of geographical regions of Europe (formula 14).

Table 4. THE DIVISION OF GEOGRAPHICAL REGIONS OF EUROPE INTO CLASSES ACCORDING TO THE VALUES OF SYNTHETIC VECTOR MEASURE AND THEIR SPATIAL HOMOGENEITY

Year	The division of Europe due to:	Europe			
		Northern	Western	Southern	Eastern
2004	the values of synthetic vector measure $(\Delta m_{s\eta})^a$	1st rank/ Class I	2nd rank/ Class II	3rd rank/ Class III	4th rank/ Class IV
	spatial homogeneity $(hl_{\sigma})^b$	28.36%	29.04%	30.75%	21.04%
2008	the values of synthetic vector measure $(\Delta m_{s\eta})^a$	1st rank/ Class I	2nd rank/ Class II	3rd rank/ Class III	4th rank/ Class IV
	spatial homogeneity $(hl_{\sigma})^b$	34.25%	29.80%	37.63%	22.33%
2014	the values of synthetic vector measure $(\Delta m_{s\eta})^a$	1st rank/ Class I	2nd rank/ Class II	4th rank/ Class IV	3rd rank/ Class III
	spatial homogeneity $(hl_{\sigma})^b$	24.59%	19.41%	21.24%	26.62%

a The level of development of an average country in geographic European region. b The ratio of the maximum increase of the standard deviation to the width of the class.

Source: own calculations.

The impact of the economic crisis on the ordering of the EU countries in four geographical regions of Europe is particularly obvious in the Southern and Eastern European Union countries. The position of the Southern countries, that had to cope with the world economic and financial crisis deteriorated and they fell in 2014 into the fourth typological group at the lowest level of development. Before the crisis those countries belonged to the third group. In contrast, the position of

the East European countries improved – they appeared the most immune to the crisis and in 2014 were promoted to the third typological group from the group IV where they were classified in 2004 and 2008. According to the study results, geographical regions of the EU represent an average level of homogeneity of the sustainable development distribution. The results of spatial homogeneity of sustainable development in 2008 and 2014 are shown on figures 3–4.

The influence of the world crisis on the development slowdown can be clearly seen. In 2008 in the case of three out of four analysed geographical regions (Northern, Southern and Western Europe) more disturbances in their spatial homogeneity ($h_{j\sigma} > 29\%$) were observed than in the case of the Eastern Europe ($h_{j\sigma} = 22.33\%$). This situation was probably due to the aforementioned resistance to the crisis of such economies as Poland, the Czech Republic, Slovakia or Hungary. However, in 2014 the countries of this part of the EU saw more imbalance in the sustainable development levels than other regions (the highest value of $c_{j\sigma}$ in the case of this regions of Europe). However, it should be noted that in that year in none of the regions the imbalance exceeded 27%.

Figure 3. The division into classes due to the value of the synthetic measure of the sustainable development in 2004.

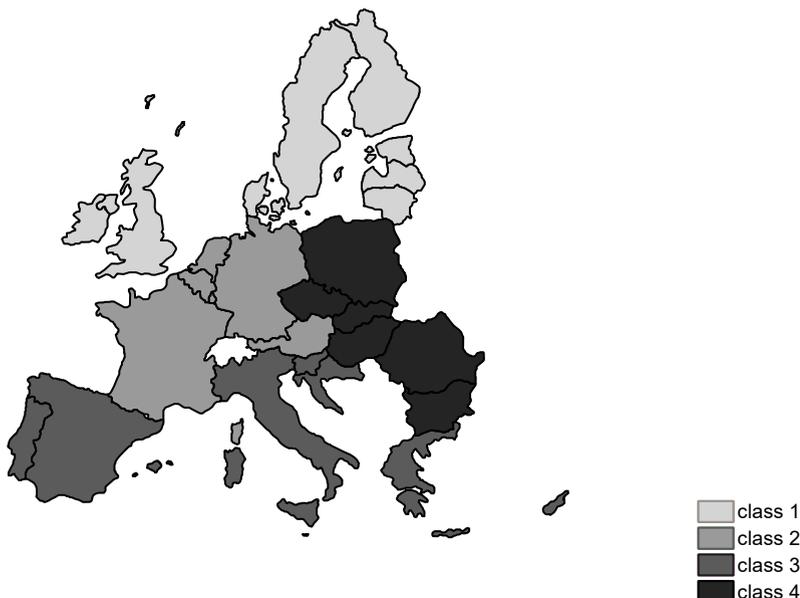
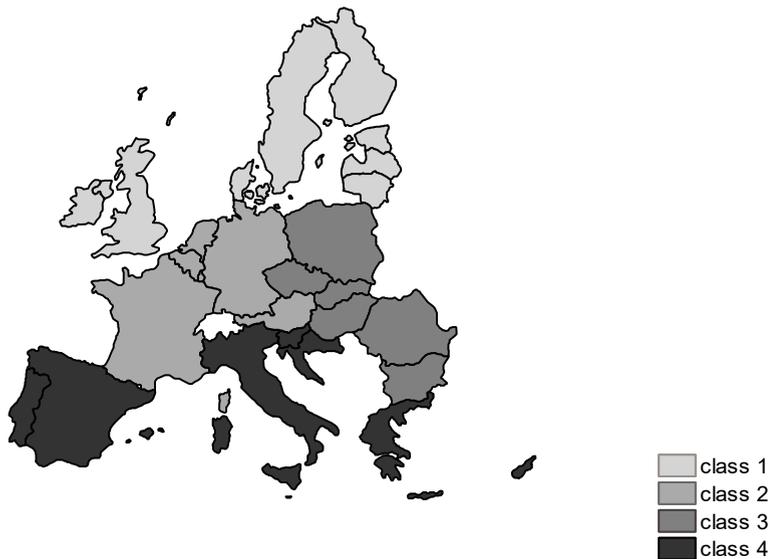


Figure 4. The division into classes due to the value of the synthetic measure of the sustainable development in 2014.



Source: own elaboration.

4. CONCLUSIONS

In the paper the results of the analysis of the spatial uniformity on the basis of sustainable development indicators published by Eurostat were presented. To the study of the spatial uniformity the taxonomic measure of development based on median Weber vector as well vector calculus were used. On the basis of the results of the analysis the spatial differences between the EU countries and the European geographical regions was confirmed. It should be noted, that according of the results of these analysis the improvement of the position taken by Eastern EU countries in the ranking and the deterioration of this position taken by the Southern EU countries were observed.

The same results was noted by others authors (e.g. Klenert et al., 2015; Kobayashi, Shirai, 2016). These authors indicate that the division of the European Union into 'better' West European countries and 'worse' Eastern Europe, or 'old' developed and 'new' developing Union or the founding countries and the remaining member states, are still synonymous to the differences in the EU development. The map of divided Europe has changed a little after the economic and financial crisis when it turned out that it was the Eurozone countries in the South that suffered most of all. According to the report *Central Europe Fit for the Future* (Nic, Świeboda, 2014) published by the think-tanks of the Central European

Policy Institute in Bratislava and the Warsaw demosEuropa: "North-South axis has largely replaced the old one between 'West' and 'East'." The authors of the report also point out that the term 'new Europe' no longer denotes 'the newly introduced to the club of rich old democracies' but refers to the countries which, despite their difficult history, have proven their capacity to transform politically and socially and managed to cope with the crisis better than the countries in the South, and even in the North of the Europe. A good example are the Baltic countries that suffered from the 2009 recession at the level of almost 20% of their GDP, but several years later, having implemented painful reforms, met the Eurozone membership criteria and today are developing at the faster rate than any member of the EU. According to Eurostat data base, in 2015 Polish GDP per capita reached 38.7% of the EU average. In the same year in the Czech Republic, which entered the Union with better economy than Poland, GDP per capita was at 54.1% of the European average, in Slovakia – 50.1%, and in Slovenia – 65.0% – i.e. more than in Portugal (60.3%) or Greece (56.4%). What is more, most of these countries have much worse transport infrastructure and their expenditure on R&D is much lower than in the rest of Europe, except Slovenia which spends 2.39% of its GDP (in comparison to Germany with 2.87%).

Catching up with the rest of Europe in this and other areas will take another decade. The negative effect of the crisis on the sustainable development of the EU countries is particularly present in the South European countries the majority of which found it difficult to survive the economic slowdown. However, the situation has improved in Eastern Europe. Moreover, the Western and Northern European Union countries have strengthened their position in the rankings measuring the rate of their sustainable development.

The results obtained in this study can be used in subsequent years to examine the direction of changes in sustainable development levels observed both from the point of view of the EU Member States and geographical regions. The analyses of the Union's internal homogeneity in this aspect will be particularly useful. The methods applied in this study, such as Weber point and vector analysis, as well as the adopted procedure of selecting diagnostic features allowed for tracking the changes in sustainable development levels not only through the prism of individual SD indicators, but also in reference to many features explaining the EU sustainable development.

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BADANIE PRZESTRZENNEJ JEDNORODNOŚCI ZRÓWNOWAŻONEGO ROZWOJU UNII EUROPEJSKIEJ PRZED, W TRAKCIE I PO KRYZYSIE EKONOMICZNYM

Streszczenie

Celem pracy jest analiza przestrzennej jednorodności w obszarze zrównoważonego rozwoju Unii Europejskiej oraz regionów geograficznych Europy rozpatrywanych z punktu widzenia krajów członkowskich UE położonych w tych regionach przed, w trakcie i po kryzysie ekonomicznym z lat 2007–2008. W analizach podobieństw i różnic rozwojowych występujących pomiędzy krajami członkowskimi Unii Europejskiej i w przypadku regionów geograficznych Europy wykorzystano wskaźniki zrównoważonego rozwoju publikowane przez Eurostat. Do ostatecznego zbioru cech diagnostycznych, które stały się podstawą dalszych badań empirycznych, wybrano 22 wskaźniki. Do badania przestrzennego zróżnicowania w obszarze zrównoważonego rozwoju wykorzystano taksonomiczny miernik rozwoju wyznaczony w oparciu o medianę Webera oraz rachunek wek-

torowy. Wpływ kryzysu na uszeregowanie krajów członkowskich UE jest szczególnie widoczny w przypadku krajów Europy Południowej i Wschodniej. Pozycja krajów Europy Południowej, które najgorzej poradziły sobie ze światowym kryzysem gospodarczym i finansowym pogorszyła się, a kraje te zostały zaklasyfikowane do grupy o najniższym poziomie rozwoju przeciętnego kraju członkowskiego. Otrzymane wyniki mogą być wykorzystane w kolejnych latach do badania kierunków zmian zachodzących w obszarze zrównoważonego rozwoju analizowanych zarówno z punktu widzenia pojedynczych państw członkowskich UE, jak i regionów geograficznych Europy.

Słowa kluczowe: zrównoważony rozwój, Unia Europejska, wielowymiarowa analiza porównawcza, mediana Webera, rachunek wektorowy

STUDY OF SPATIAL UNIFORMITY OF SUSTAINABLE DEVELOPMENT OF THE EUROPEAN UNION BEFORE, DURING AND AFTER THE ECONOMIC CRISIS

Abstract

The purpose of the paper is study of spatial uniformity in the field of sustainable development of European Union and geographical regions of Europe analyzed by the prism of EU countries located in this regions before, during and after the economic crisis from 2007–2008.

Material and methods The analysis of similarities and differences between the EU Member States countries or in the case of geographic regions of Europe has been based on sustainable development indicators published by Eurostat. To the final set of diagnostic features, the 22 indicators have been selected. To study the spatial differentiation of sustainable development the taxonomic measure of development based on median vector Weber as well vector calculus were used. The impact of the economic crisis is particularly obvious in the Southern and Eastern European Union countries. The position of the Southern countries, that failed to cope with the world economic and financial crisis, deteriorated and they fell into the group at the lowest level of development. The results obtained in this study can be used in subsequent years to examine the direction of changes in sustainable development levels observed both from the point of view of the EU Member States and geographical regions.

Keywords: sustainable development, multidimensional comparative analysis, the European Union, vector calculus, Weber median