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MULTIDIMENSIONAL COMPARATIVE ANALYSIS OF THE LEVEL OF SUSTAINABLE DEVELOPMENT OF THE EUROPEAN UNION MEMBER STATES USING TAXONOMIC METHODS

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Abstract

The aim of the paper is an identification and assessment of the level of sustainable development of the European Union members states using taxonomic methods. The starting point for conducting the multidimensional comparative analysis was adopting three sets of diagnostic variables characterizing the level of sustainable development of the analyzed European Union members states in terms of their fundamental dimensions, i.e. social, economic and environmental. The main tool used for creating the ranking was the method of standardized sum of PERKAL indicator, which made possible conducting a classification procedure based on analysis and ordering objects described by means of many diagnostic variables. The paper used numerical data published by EUROSTAT in 2016. Performing the multidimensional comparative analysis for the regions in Poland and Slovakia allowed to order them according to the value of determined synthetic measure and classification to three groups revealing different levels of sustainable development. The results of conducted analysis indicate considerable differences of the studied objects both due to their economic, social and environment dimensions, and in the context of their sustainability level.

Keywords: *sustainable development, taxonomic methods, multidimensional comparative analysis, ranking, the European Union member states.*

JEL classification: *C43, Q51, Q56, R11, R58*

1 Introduction

New ideas and concepts usually originate in the minds of individuals or owing to collective wisdom. In case of sustainable development the second statement is the appropriate one (Bołtromiuk, 2011). The main reason why an intensive debate was initiated by the end of the seventies of the 20thcentury on creating a new approach to the problem of the world economic growth was apparently an increasing disparity between the level of development of individual countries and their regions resulting from the irrational model of natural resources management (Du Pisani, 2006). Currently, the paradigm of sustainable development plays an important role in modelling the attitude towards mutual social relationships, economy and the environment which translates itself into the intensity of changes of the way in which global and local economic systems function (Rogall, 2010). On one hand, the phenomenon seems a natural requirement of the time flow, on the other it may evidence more and more conscious responsibility for the fate of future generations (Paluch, 2013).

A different outlook on the place of modern man in the surrounding environment has been evidenced among others by the ideas of equivalence, sustainability and self-support of socio-economic and environmental development strongly embedded in the European and international legislation and legal order (Bugge & Voigt, 2008). Despite a scientific and institutional discussion, which has been going on for almost four decades, so far no detailed or universal method have been developed allowing undertaking the activities to guarantee full realization of principles and objectives of sustainable development on various levels of territorial units (countries, regions or cities) (Zhu & Hua, 2017). This state of affairs is caused, among others by a diverse approach to the ways in which sustainable development is assessed, which results from both the lack of explicit meaning of the term and its multidimensional character (Glavic & Lukman, 2007; Pater & Cristea, 2016). The issues mentioned above are characterized by complexity and unreliability, whereas their recognition and solving require a comprehensive and interdisciplinary understanding. Therefore, scientists and institutional experts, who want to use the appropriate methodology constantly develop new modifications for the measurement and assessment of sustainable development. However, most of these proposals focus mainly on the assessment of its compliance with the objectives stated in the strategic and planning documents of national or international importance, while often omitting the analysis of homogeneity of changes in various economic systems over space and time (Liu, Brown & Casazza, 2017). It is commonly believed that a new paradigm of world development implementation should be based on the ability to establish whether it meets and will meet in future the criteria of equality and sustainability of social, economic and environmental changes, or will be unable to meet them (George, 1999).

Due to its multidimensionality, sustainable development requires the publication of appropriate methods and determining the sets of quantifiable measures (features, variables, indices), which despite the limitation of sources will allow to conduct potentially detailed comparative analysis of the individual dimensions (components) of development of countries and their regions over time and space (Robert, Parris & Leiserowitz, 2012; Szopik-Depczyńska, Cheba, Bąk, Kiba-Janiak, Saniuk, Dembińska & Ioppolo, 2017). In case of measuring and assessment of such complex process, the key aspect becomes a necessity to reconcile the description of its permanence and sustainability in the social, economic and environmental dimension with the requirements of comparability, simplicity and easy applicability of the diagnostic variable which describes it. However, creating the measures of this kind is not easy. Selection and the way in which they are used, which in each situation constitutes a resultant of the data availability and arbitral decision of a scientist, determine the results of conducted analyses providing a basis for the projection of system changes serving for the implication of efficient solutions in diverse conditions of development of individual territorial units (countries, regions and cities). Therefore, for some decades, a measurement of sustainable development level has been a sphere of scientific research, where the prerequisite for obtaining reliable information means developing an appropriate set of indices, methods and tools for its assessment (Hassan, Haddawy & Zhu, 2014; Balas & Molenda, 2016).

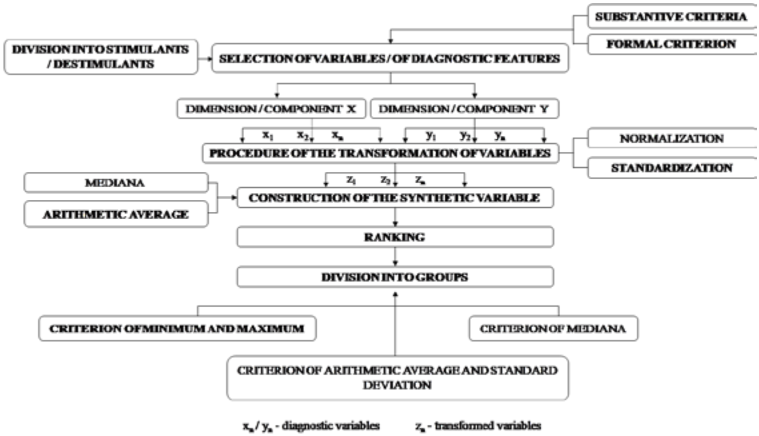
So, the aim of the paper is an attempt at application of the PERKAL method of standardized sums, which is one of taxonomic methods, to conduct a comparative analysis of the sustainable development level in the European Union member states.

2 Data and Methods

Taxonomic methods are among the statistical tools which are the most frequently used to research complex phenomena . The starting point in a taxonomic analysis is a set of objects (e.g. countries, regions or cities) which are the subject of research, characterized by means of a set of diagnostic variables (features and indices) (Kukuła, 1999). The main idea behind the methods of this kind relies on passing from multidimensional arrangement of features to unidimensional arrangement through their aggregation based on model or non-model formulas (Bąk & Szczecińska, 2014). The measurement and assessment of a complex phenomenon are therefore conduced in the context of numerical description of its individual spheres, dimensions or components constituting the value of synthetic variable or synthetic measure, which is a function combining into one all partial information carried by the assumed set of diagnostic variables. Another property of a synthetic measure is its possible application for the assessment of disproportions occurring in a given space and time horizon (Paluch & Satoła, 2017). The synthetic measure created on the basis of diagnostic variables is devoid of identity, which allows it to be used for constructing a ranking and dividing the objects into groups of diversified level of the studied phenomenon development. At present it is difficult to disregard a considerable importance of rankings of various sets of objects made on the basis of predetermined criteria. At so fast information flow observed currently their results may provide a basis for decision making and activities targeting economic, social, environmental, institutional or political changes (Kukuła, 2000).

One of the statistical tools used in the research on multidimensional phenomena is PERKAL method of standardized sums, which belongs to the group of taxonomic methods. Its basic instrument used during linear ordering of objects characterized by many diagnostic features, called PERKAL indicator (*SWP*), which is a function combining partial information carried by the set of diagnostic variables assumed for the analysis. The method comprises four successive stages: selection of features, their standardization, construction of synthetic measure, ordering and classification of objects according to the level of the analyzed phenomenon (Brol, Kusideł, Maciejuk, Markowska, Obrębalski, Sobczak, Strahl, Sztando & Zapart, 2006) (Figure 1).

Figure 1 **Simplified scheme of the objects classification procedure using taxonomic methods**



Source: Author`s elaboration based on Paluch, 2015.

The starting point for the comparative analysis on the level of sustainable development using the PERKAL method of standardized indicators sum was therefore suggesting three sets of diagnostic variables (features) characterizing its basic dimensions, i.e. social, economic and environmental. The main source of numerical data for the research was provided by the European Statistical Office (EUROSTAT) database and at their selection it was assumed that they would refer to 2016-2017, would be reliable, precise, comparable, adequate and complete concerning the time and space (Grabiński, 1984). The selection of the final list of diagnostic variables from among the available statistical data published by EUROSTAT was based on the substantive criteria, including the aim, subject of research and its time frame and formal criterion comprising testing the strength of correlation relationship between diagnostic features and the level of their variability (Table 1).

Table 1 **Final set of diagnostic features**

Social dimension (so_n)		Year
$so_{1\,(S)}$	activity rate (% of total population aged 15-64)	2016
$so_{2\,(S)}$	rate of migration (per 1 000 inhabitants)	2016
$so_{3\,(S)}$	employment in high and medium-high technology manufacturing sectors and knowledge (% of total employment)	2016
$so_{4\,(D)}$	people at risk of poverty or social exclusion (% of total population)	2017

Social dimension (so_n)		Year
$so_{5\,(S)}$	adult participation in learning (% of population aged 25-64)	2016
$so_{6\,(S)}$	total fertility rate (number of children per woman)	2016
$so_{7\,(D)}$	low reading literacy performance of pupils (up to 15 years old)	2016
$so_{8\,(D)}$	housing cost overburden rate (% of the population living in a household where total housing costs represent more than 40% of the total income)	2016
Economy dimension (ec_n)		
$ec_{1\,(S)}$	real GDP per capita in PPS (EU28 = 100)	2016
$ec_{2\,(D)}$	HICP inflation rate (%)	2017
$ec_{3\,(S)}$	total investment by institutional sectors (% of GDP)	2016
$ec_{4\,(D)}$	general government gross debt (% of GDP)	2016
$ec_{5\,(D)}$	total unemployment rate (%)	2017
$ec_{6\,(S)}$	R&D expenditures (% of GDP)	2017
$ec_{7\,(S)}$	eco-innovation index (EU28 = 100)	2016
Environmental dimension (en_n)		
$en_{1\,(D)}$	gross inland consumption of energy divided by GDP (kg of oil equivalent per 1000 EURO)	2015
$en_{2\,(D)}$	greenhouse gas emissions index (in CO_2 equivalent, base year 1990)	2015
$en_{3\,(S)}$	shares of environmental and labour taxes in total tax revenues from taxes and social contributions (%)	2016
$en_{4\,(S)}$	electricity generated from renewable sources (% of gross electricity consumption)	2016
$en_{5\,(D)}$	generation of municipal waste per capita (kg per person)	
$en_{6\,(S)}$	environmental tax revenues (% of GDP)	2016
$en_{7\,(S)}$	protected forests and forests under Natura 2000	2015
$en_{8\,(S)}$	resource productivity (EURO per kg)	2016
$en_{9\,(S)}$	area under organic farming (% of UAA)	2016

Source: Author's elaboration based on data base of European Statistical Office. Retrieved from http://ec.europa.eu/eurostat.

In order to test the assumed set of variables in terms of fulfillment of the formal requirements, the assumption was made that they should be weakly correlated among one another and reveal relatively high degree of variability. The degree of their interrelationship was tested by means of PEARSON correlation coefficient (r_{ij}), and in order to eliminate the features of high interrelationship, it was assumed that two highly correlated variables are carriers of similar information, so one of the pair is useless for the analysis. Linear correlation coefficient (r_{xij}) may assume values from [-1,1] range, where the value r_{ij}= 1 or -1, indicates that a functional dependence occurs between a pair of variables, whereas if $r_{ij} = 0$, the tested features are not correlated, which means that no bonds occurs between them (Stanisz, 2006). The range of variability, i.e. diversification of diagnostic variables values within the set of analyzed objects was determined using variation coefficient ($V(x_{ij})$ expressed in percent. It is commonly believed that the value of variability of the set of features for which ($V(x_{ij}) \leq 10\%$ should not be used to seek the causative agents of the investigated phenomenon. Therefore, diagnostic variables for which ($V(x_{ij})$ does not fulfill the inequality $0 \leq V(x_{ij}) \leq 0{,}1$ are "quasi-fixed" variables, so it should be eliminated from further analysis (Parris & Kates, 2003).

An important stage of selection of features describing individual dimensions of sustainable development was also determining the influence of individual features on the investigated phenomenon. Their character was identified by stating whether the variables assumed for the analysis represent a positive or negative effect on its course. Testing their identity led to the classification of individual features to one of the two subsets, i.e. stimulants (*S*), whose higher values indicate a high level of the studied phenomenon level or destimulants (*D*), where their high values evidence a distant position in the constructed ranking. In case of diagnostic variables assumed for the assessment of sustainable development of the EU countries, the stimulant set was composed of : so_1,so_2, so_3, so_5, so_6, ec_1, ec_3, ec_6, ec_7, en_3, en_4, en_6, en_7, en_8, en_9, whereas the following ones obtained the status of destimulants: so_4, so_7, so_8, ec_2, ec_4, ec_5,en_1, en_2 and en_5.

Identification of diagnostic variables character was a basis for their transformation process in order to lead to comparability. These features are expressed by means of various measurement units, with various accuracy and their values area is characterized by different range of variability. Therefore it was necessary to unify and set a fixed span range for their values. The tool used for the unification of selected diagnostic features was standardization method, which constitutes such a form of quotient mapping, in which the values of standardized feature (x_{ij}) or this feature diminished by its arithmetic average $lnNCE = lna + b_1 lnNGMWE + b_2 lnRPR$ are referred to the values of standard deviation ($S(x_j)$). One of the oldest and most frequently used methods standardizing diagnostic variables, i.e. bringing them to abstract numbers with unified order of magnitude is standardization based on the formulas presented below (Perkal, 1953):

$$z_{ij} = \frac{x_{ij} - \bar{x}_j}{S(x_j)},\ x_j \in S,\ z_{ij} \in \frac{\min \bar{x}_j}{S(x_j)}, \frac{\max x_{ij} - \bar{x}_j}{S(x_j)} \quad (1)$$

$$z_{ij} = \frac{\bar{x}_j - x_{ij}}{S(x_j)},\ x_j \in D,\ x_{ij} \in \frac{\bar{x}_j - \max x_{ij}}{S(x_j)}, \frac{\bar{x}_j - \min x_{ij}}{S(x_j)} \quad (2)$$

where: z_{ij} – value of diagnostic variable after standardization, x_{ij} – value of diagnostic variable, $NCE = 1.77 * NGMWE^{0.82}$ * – arithmetic average, $S(x_j)$ – standard deviation, S – set of stimulants, D – set of destimulants.

The standardized features were then used for constructing PERKAL indicator (*SWP*), whose property is ordering a complex phenomenon by means of a single numerical measure, in this case the arithmetic average (Młodak, 2006)

$$SWP = \frac{\sum_{i=l}^{n} z_{ij}}{n},\ (i = 1,2,\dots,r)(3)$$

where: SWP – value of PERKAL indicator, z_{ij}– value of diagnostic variable after standardization, n – number of investigated objects.

The values of determined PERKAL indicator (*SWP*) allowed to establish a ranking of the EU member countries according to their development level in the socio-economic ($SWP_{so\text{-}ec}$) and environmental (SWP_{en}) dimensions. This index also made possible the classification of the studied objects to three typological groups with diverse level of development (Table 2).

Table 2 **Criteria of the EU countries division into groups with diversified levels of socio-economic and environmental development**

Group	Criteria of division
I_n	max(SWP) - 1/3[max-min (SWP)] ≤ SWP ≤ max(SWP)
II_n	max(SWP) - 2/3[max-min (SWP)] ≤ SWP ≤ max(SWP) - 1/3[max-min(SWP)]
III_n	min (SWP) ≤ SWP ≤ max(SWP) - 1/3[max-min(SWP)]

Source: Author`s elaboration based on Kukuła, 2000.

Basing on the determined values of PERKAL indicators ($SWP_{so\text{-}ec}/SWP_{en}$) and affiliation of the studied EU countries to the groups with diversified level of development in the socio-economic ($I_{so\text{-}ec}/II_{so\text{-}ec}/III_{so\text{-}ec}$) and environmental ($I_{en}/II_{en}/III_{en}$) dimensions, they were classified to three typological groups representing different levels of sustainable development (A/B/C) (Table 3).

Table 3 **Criteria of the EU countries division into groups with diversified levels of sustainable development**

Group	Criteria of division
A	$SWP \in I_{so\text{-}ec} \wedge I_{en} \vee SWP \in I_{so\text{-}ec} \wedge II_{en} \vee SWP \in II_{so\text{-}ec} \wedge I_{en}$
B	$SWP \in II_{so\text{-}ec} \wedge II_{en} \vee SWP \in I_{so\text{-}ec} \wedge III_{en} \vee SWP \in III_{so\text{-}ec} \wedge I_{en}$
C	$SWP \in II_{so\text{-}ec} \wedge III_{en} \vee SWP \in III_{so\text{-}ec} \wedge II_{en} \vee SWP \in III_{so\text{-}ec} \wedge III_{en}$

Source: Author`s elaboration.

The minimum and maximum values of PERKAL indicator were used for the groups formation, and the presented division criteria indicate, that the higher the value assumed by the synthetic measure (*SWP*), the higher the level of the phenomenon which characterizes a given object, which caused its classification to individual group in an ascending order, i.e. group I or A is composed of the objects with the highest level, units with medium levels were classified to group II or B, whereas group III or C comprises objects with the lowest level of the studied phenomenon development.

3 Results and Discussion

In the subject literature one may frequently encounter a statement that apparent disproportions concerning the level of socio-economic and environmental development, as compared with the "former fifteen" (EU-15) countries, refer particularly to the Central and East European countries, which joined the European Union after 2004, i.e. Cyprus, Czech Republic, Estonia, Lithuania, Latvia, Malta, Poland, Slovakia, Slovenia, Hungary and Croatia (Stec, 2008; Dominiak & Churski, 2012, Bluszcz, 2016; Maciejewski, 2017). The results of the assessment of sustainable development level by means of PERKAL method provoke similar conclusions (Table 4).

Table 4 **Division of the EU member countries into groups with diversified level of development in the socio-economic and environmental dimension**

Member States	SWP so-ec	Group	SWP en	Group	Member States	SWP so-ec	Group	SWP en	Group
Austria	0.47	I	0.28	II	**Italy**	-0.39	II	0.17	II
Belgium	0.07	II	-0.22	III	**Latvia**	-0.34	II	0.68	I
Bulgaria	-0.80	III	-0.38	III	**Lithuania**	-0.48	II	-0.22	III

Member States	SWP so-ec	Group	SWP en	Group	Member States	SWP so-ec	Group	SWP en	Group
Croatia	-0.54	II	0.26	II	**Luxembourg**	0.44	I	-0.47	III
Cyprus	-0.61	III	-0.57	III	**Malta**	0.02	II	-0.46	III
Czech Republic	0.44	I	-0.12	III	**Netherlands**	0.45	I	0.12	II
Denmark	0.87	I	0.29	II	**Poland**	-0.23	II	-0.11	III
Estonia	0.12	II	0.15	II	**Portugal**	-0.38	II	-0.04	II
Finland	0.79	I	0.05	II	**Romania**	-0.70	III	0.11	II
France	0.37	I	0.19	II	**Slovakia**	-0.08	II	-0.13	III
Germany	0.61	I	-0.34	III	**Slovenia**	0.16	II	0.29	II
Greece	-1.38	III	0.13	II	**Spain**	-0.35	II	-0.24	III
Hungary	-0.12	II	-0.23	III	**Sweden**	1.02	I	0.45	I
Ireland	0.41	I	-0.35	III	**United Kingdom**	0.17	II	0.13	II

Source: Author's elaboration based on data base of European Statistical Office. Retrieved from http://ec.europa.eu/eurostat.

The division of the analyzed community in terms of the socio-economic development level reveals that from among the above mentioned countries Bulgaria, Romania and Cyprus were included in group III (with the lowest level of development). Although Lithuania, Latvia, Poland, Hungary and Slovakia were classified within group II (with medium level of development), yet worthy of note are their low values of synthetic measure (*SWP*), which considerably differ from the other countries in the same group. Czech Republic is the exception among the so called "new" EU member states, as together with Sweden, Denmark, Finland, Germany, Austria, Holland, Luxembourg, Ireland and France was classified to group I (with the highest level of development). It should be also noted that the group of units with the highest level of socio-economic development does not contain the Mediterranean countries (Greece, Portugal, Spain or Italy) which, despite the economic success in the initial years after their accession into the EU, currently face serious social and economic problems being the aftermath of the global economic crisis (Piecuch, 2017).

Considering the EU countries assessment in the environmental dimension, the Scandinavian countries (Sweden, Denmark and Finland) received one of the top marks. They are characterized by a Nordic model of development based on a long-standing tradition of economic and political cooperation and activities focused on the shaping and protection of the natural environment. The cooperation contributed to an intensive rate of economic growth and development of a social and environmental culture, unique in the world, focused on implementation of sustainable and permanent development concepts, which should be an example for other EU countries (Zapędowska-Kling, 2013; Frączek, 2014). It has been substantiated by the fact, that according to the conducted assessment the countries were classified as the units with the highest level of sustainable development (Figure 1).

Figure 1 **Spatial diversification of the level of sustainable development in the EU member states**

Source: Author`s elaboration.

The following countries were classified to the group with the lowest level of sustainable development: Cyprus, Greece, Spain, Lithuania and Malta. It is worth noticing, that also the countries of the Visegrád Group, i.e. Poland, Hungary, Slovakia and Czech Republic were included in the same group, which despite similarities, such as their location, level of development and economic history, differ considerably from one another by their way of carrying out social, economic and environmental policy, which may be evident as a lack of coherence and consequence in the issues concerning the shape of sustainable development in the Central and East European countries (Drews, 2016).

The European Union and its legal, political, institutional and market structures constitute a form of the countries integration, unique in the world. The countries connected with one another by a number of supranational treaties constitute a significant socio-economic and environmental force in a global context (Dunning & Ludan, 2008). As indicated by the results of conducted assessment, on one hand, the diversity of the economies of the old continent countries is the driving force for their competitiveness in the world, on the other causes many difficulties in the harmonious and effective implementation of the measures for the sustainable development. Because of big and constantly increasing disparities among the EU countries and regions, reducing the internal disproportions has been one of its main strategic objectives, yet so far no balance in this area has been achieved (Grupa &Kozieł, 2015). Irrespective of the regional policy implemented in the Community and supported by its instruments, such as the structural funds, loans from the European Central Bank and Cohesion Fund, so called "new " EU members have been unable so far to catch up on the considerable differences in relation to EU-15 countries. The differences limit their development possibilities, which decreases the dynamics of the integration processes inside the EU, therefore making difficult realization of goals and assumptions of the development paradigm based on the permanence and sustainability principles.

4 Conclusion

Conducted research allows to conclude that, because of diversified conditionings (causative agents), sustainable development of the EU countries does not progress evenly in spatial terms. The diversifying factors are both socio-economic and environmental resource, which usually initiate the concentration of material and financial capital, thus determining the character and rate of changes concerning human settlement, structure of economy and labour market, but also those concerning technical infrastructure, financial situation, innovation of economy and its institutional environment, as well as the state and quality of the natural environment. Their occurrence more and more frequently becomes also a limitation to the realization of the main objectives sustainable development, i.e. equality, permanence and self-sustainability of the socio-economic and environmental development. Another barrier in this respect may be posed also by increasingly more apparent disproportions in the level of development, which deepen the phenomenon of economic polarization, which usually enhances the process of changes in highly developed areas at the simultaneous plunging into stagnation of underdeveloped regions.

Application of PERKAL method of standardized sum, which belongs to the taxonomic methods group, allowed to identify the diversification of the sustainable development level in the EU member countries. It is worth noticing, that an undoubted advantage of the applied methodological approach is a possibility to conduct a multidimensional comparative analysis not only in the spatial but also time context. Taxonomic methods base on rankings, where a change of a given object position reflects the results of changes occurring in time and space, in which the object is situated. Presented results may be therefore used in the subsequent years to follow the directions of changes of the development level in the EU countries in three main dimensions, i.e. social, economic and environmental. However, one should keep the obtained results in perspective because of the effect of external agents, usually unpredictable, which may undoubtedly disturb a number of initiated development processes in the community, postponing or even eliminating the expected results of model activities, particularly in view of new challenges which EU faces, including economic crises, global migration processes or so called BREXIT.

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