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MULTIDIMENSIONAL COMPARATIVE ANALYSIS OF SUSTAINABLE DEVELOPMENT IN EUROPEAN UNION

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Abstract. The main purpose of the paper is to assess the comparative level of sustainable development of European Union countries. Posing such questions is particularly important in the case of such political and economic structures as European Union. The analyses conducted in the paper 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 socio-economic realities. To study the spatial differentiation of social and economic development, on the basis of sustainable development indicators presented by Eurostat, the taxonomic measure of development based on median vector Weber was used. The results obtained in this study can be used in subsequent years to examine the direction of changes in sustainable development levels observed from the point of view of the EU Member States. The results obtained in the work confirm the significant differences between the EU countries in the field of sustainable development. These differences are especially visible between the countries located in different geographical area of Europe (such as Northern and Western Europe and Southern and Eastern Europe).

Key words: sustainable development, multidimensional analysis, European Union.
JEL code: C38, O11, P36.

Introduction

The European Union with its structure, which is composed of sovereign nations, is a significant global force. This structure and the combined total of many vastly varying economies can, on the one hand, determine the power of the EU economy, while on the other - it can disturb its harmonious operation. Balanced development of the Member States of European Union is one of the strategic objectives of further EU functioning and it can and should be considered in reference to numerous areas of the EU operation, like a sustainable development (Report…, 1997).

Dynamic changes noted on the world markets, which are predominantly connected with economic slowdown, coerce the consideration of the uniformity of development of each region. 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 (2004) and after the economic slowdown in 2007-2008 (2014). 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 and often completely different social and economic realities. The previous study by the authors (Bak I., 2014; Cheba K., 2015) 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 received on the basis of data on indicators of sustainable development, analysed separately before and after the period of economic slowdown.

The main purpose of the paper is to assess the comparative level of sustainable development of the European Union countries. Posing such questions is particularly important in the case of such political and economic structures such as the European Union. We would like to try to find also an answer to the question, whether it is possible to talk in today's globalizing world about the uniform socio-economic development? The results presented in the work will contribute to increasing knowledge about the level of sustainable development of the EU countries. To study the spatial differentiation of social and economic development the taxonomic measure of development based on median vector Weber has been used.

Methodology of the study

The research method in this paper consists of three tasks (Fig. 1).

In the first task, the critical analysis of the foreign and Polish literature has been analysed. On the basis of analysis of the literature, the

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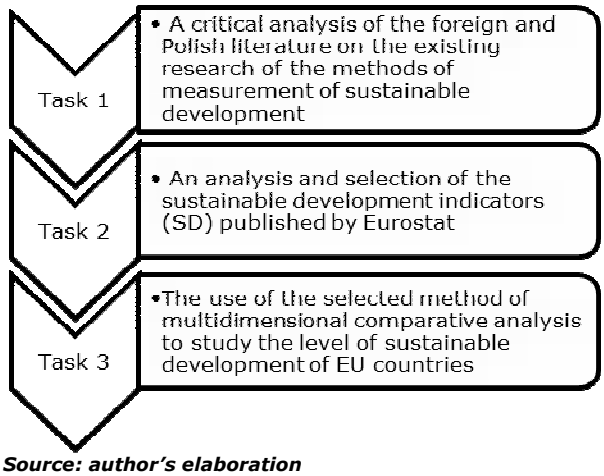
existing research of the method of measurement of sustainable development was analysed.

In the next task, the analysis and selection of the sustainable development indicators published by Eurostat were carried out. At the beginning of the study, a database was set up. The original database included 47 indicators describing 12 themes of European sustainable development. Due to the shortage of data about some of the indicators in 2004 and 2014, those indicators were excluded from the study.



Source: author's elaboration

Fig. 1. **Research method**

Then, in the last task of the study a selected method of multidimensional comparative analysis to study the level of sustainable development of the EU countries was implemented. In the work, the taxonomic measure of development based on median vector Weber and vector calculus was used.

The measurement of sustainable development in the European Union

In the literature, the problem of sustainable development is widely discussed. A sustainable development is very often presented in the context of:

- theories and economic models (Hopwood B. et al., 2005; Eagle N. et al., 2010; Bal-Domanska B. and Wilk J., 2011; Stefanescu D. and On A., , 2012; Boda et al., 2015; Duran et al., 2015, Sustainable …, 2015).
- its relationship with ecology (Ciazela H., 2005; Borys T., 2011);
- philosophy (Borys T., 2011; Dutta U., 2016;).

An important area of this study is primarily a measurement of sustainable development comprising of identification of indicators of sustainable development (SDI) or analysis of these indicators in different areas of this field.

In the European Union, the implementation of the EU Sustainable Development Strategy (EU SDS) is monitored by means of the Sustainable Development Indicators (SDI) published by Eurostat (Sustainable…, 2015).

The SDIs have a hierarchic structure whose components are divided into three levels. At the top, there are 11 Headline Indicators that are intended to give an overall picture of the progress in terms of the key challenges of the EU SDS. The second level is represented by of 31 Operational Indicators that relate to the operational objectives of the Strategy, while at the third, lowest level there are 84 Explanatory Indicators that illustrate the progress of the actions described in the SDS.

In this work, to assess similarities and differences at the level of sustainable development of the EU Member States the sustainable development indicators published by Eurostat have been used.

Database

In total, the Eurostat database collected information about 126 indicators describing sustainable development (Table 1).

However, not all of them are available at the individual level of the EU Member States (e.g. in the case of indicators describing the area of natural resources), both in 2004 and 2014. These restrictions meant that the original set of 126 characteristics was reduced to 74 indicators representing different areas of sustainable development, which were the final selection taking into account the statistical criteria. The selection criteria were divided into two groups: the content related and formal/statistical ones. In the first approach, the set of diagnostic characteristics contains such values that, according to the obtained knowledge about the

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phenomena under study, are the most typical of the compared objects. In the second approach, the selection of characteristics follows a specific formal procedure.

Table 1

Title

No	SD theme	Numbers of operational indicators/ explanatory/ contextual
1.	Socio-economic development	5/11/-
2.	Sustainable consumption and production	3/14/2
3.	Social inclusion	5/12/1
4.	Demographic changes	4/3/5
5.	Public health	2/7/-
6.	Climate change and energy	3/7/-
7.	Sustainable transport	4/6/1
8.	Natural resources	4/5/-
9.	Global partnership	3/9/1
10.	Good governance	3/3/1

Source: author's elaboration based on Eurostat

First, the assessment analysed the coefficients of variation calculated for each variable, taking as a criterion for the resignation of the given feature the coefficient of variation less than or equal to 10 % and in the evaluation of the correlation of variables a parametric method of selection of Hellwig features was used (Hellwig Z., 1981), taking the critical value of the correlation coefficient equal to 0.5 or higher. In this way, the original set of features was reduced to 22 indicators (where: S – stimulants and D – destimulants), (Table 2).

A research tool applied

In the work to study the spatial differentiation of sustainable development of individual countries in the European Union, the taxonomic measure of development based on median vector Weber (Weber A., 1971) was used. The median Weber is a multi-dimensional generalization of the classical notion of the median. It is about 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 immune to the presence of outliers (Mlodak A., 2006). The positional option of the linear object assignment takes a different standardization formula, compared to 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 (Weber A., 1971).

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

Where:

$\theta_0 = (\theta_{01}, \theta_{02}, ..., \theta_{0m})$ is the Weber median;

$\tilde{mad}(X_j)$ is the absolute median deviation, in which the distance from the features to the Weber vector is measured, i.e.: $\tilde{mad}(X_j) = \underset{i=1,2,...,n}{med} \left| x_{ij} - \theta_{0j} \right| \ (j = 1,2,...m)$.

The aggregate measure is calculated with the formula:

$$\mu_i = 1 - \frac{d_i}{d_-} \quad (2)$$

Where:

d_- =med(**d**)+2,5mad(**d**), where $d=(d_1, d_2,\ldots,d_n)$ is a distance vector calculated with the formula: $d_i = \underset{j=1,2,...m}{med} \left| z_{ij} - \varphi_j \right| \quad i = 1,2,...,n$,

$\phi_j = \max_{i=1,2,...,n} z_{ij}$ – the coordinated 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 $\mu = (\mu_1, \mu_2, ..., \mu_n)$, which is denoted $med(\mu)$, then dividing the population of objects into two groups: those, for which the measure values exceed the median and are higher than it. Next the indirect medians

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are defined as: $\mathrm{med}_k(\mu) = \underset{i:\Gamma_i \in \Omega_k}{\mathrm{med}}(\mu_i)$, where $k = 1,2.$ This way the following groups of objects are created:

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

Table 2

Final database

No	SD area	Feature
1.	Socio-economic development	– young people neither in employment nor in education or training (NEET) (15-24 years), % of the total population in the same age group - (x_1, D); – total R&D expenditure, % of GDP -(x_2, S); – total unemployment rate, % - (x_3, D);
2.	Sustainable consumption and production	– generation of waste excluding major mineral wastes, kg per capita - (x_4, D); – final energy consumption, 1000 tonnes of oil equivalent - (x_5, D);
3.	Social inclusion	– early leavers from education and training, % - (x_6, D); – tertiary educational attainment, by sex, age group 30-34, % - (x_7, D); – long-term unemployment rate - (x_8, D); – lifelong learning, % - (x_9, S);
4.	Demographic changes	– employment rate of older workers, % - (x_{10}, S); – total fertility rate, number of children per woman- (x_{11}, S); – old-age dependency ratio, per 1000 persons - (x_{12}, D);
5.	Public health	– life expectancy at birth of males, years - (x_{13}, S);
6.	Climate change and energy	– primary energy consumption, million TOE (tonnes of oil equivalent) - (x_{14}, S); – share of renewables in gross final energy consumption, % - (x_{15}, S); – electricity generated from renewable sources, % - (x_{16}, S); – share of renewable energy in fuel consumption of transport, % - (x_{17}, S);
7.	Sustainable transport	– consumption of transport relative to GDP, index (2010-100 %) - (x_{18}, D); – energy consumption by transport mode – road transport, 1000 tonnes of oil equivalent - (x_{19}, D);
8.	Global partnership	– CO2 emissions per inhabitant in the EU and in developing countries, tonnes - (x_{20}, D);
9.	Good governance	– shares of environmental taxes in total tax revenues from taxes and social contributions, % - (x_{21}, D); – level of citizens' confidence in EU institutions (for sub-theme policy coherence and effectiveness), % - (x_{22}, S).

Source: author's elaboration based on Eurostat data

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

Research results and discussion

Table 3 shows the mean values of some Headline Indicators of the EU sustainable development as well as the measures of its diversification in 2004 and 2014. The indicators were selected due to their availability in all the years of this analysis. The choice of those years was not a random one. In 2004, the EU was joined by East European countries, this period shows the situation before the world financial and economic crisis of 2007/2008. While 2014 was the last year when the majority of the analysed indicators were available in the Eurostat database.

The results presented in the table show that in a longer time frame, progress was observed in such themes as sustainable consumption and production, demographic changes and, partially, in climate change and energy (greenhouse gas emissions indicator). Significant diversification of indicators was observed in relation to the environmental aspects of the EU development. While, the improvement was recorded in the case of indicators dependent on the economic cycle

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(being in downturn due to the economic crisis), such as greenhouse gas emissions and energy consumption. Particularly positive trends were seen in the greenhouse gas emissions whose 2012 indicator was lower only by 2 percentage points than the limit of 20 % reduction below the 1990 levels assumed in the Europe 2020 Strategy. Downward trends were observed in the social inclusion and natural resources themes.

Table 3

The descriptive statistics of SD indicators of the EU in 2004 and 2014

No	Variable	Descriptive statistics	2004	2014
1.	x_1	$\bar{x}$ Vs	20 000 68.59	25 925 65.74
2.	x_2	$\bar{x}$ Vs	1.25 60.67	1.65 60.33
3.	x_4	$\bar{x}$ Vs	40.87 27.27	51.29 19.78
4.	x_7	$\bar{x}$ Vs	19.12 8.38	20.92 7.42
5.	x_8	$\bar{x}$ Vs	15.45 10.60	17.29 10.71
6.	x_9	$\bar{x}$ Vs	97.97 31.18	81.38 32.76
7.	x_{10}	$\bar{x}$ Vs	61.03 134.99	53.83 135.41
8.	x_{11}	$\bar{x}$ Vs	104.68 7.55	100.93 5.11

Source: author's calculations based on Eurostat data, where: x – average and Vs – coefficient of variation in %

Next table (Table 4) shows the results of the classification and the typological groups of the EU countries obtained by means of the taxonomic measure of development calculated on the basis of the characteristics of their socioeconomic situation.

It is clear that 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 last in the 2004 ranking, and the 7th in 2014. Four EU countries did not see any fall in the ranking in 2004 and 2014, while 10 countries picked up in the ranking (the largest increase in Slovakia from 27th to 7th position).

The socioeconomic situation in 2014 compared to 2004 deteriorated in 14 countries – the most affected were Greece (down from the 17th to the 28th position), the Czech Republic (the fall from the 10th to the 20th position). Hungary and Ireland went down by nine positions.

Table 4

The EU countries sorted by the social and economic development in 2004 and 2014

No	Country (value of mater - μ_i)	Group	Country (value of mater - μ_i)	Group
	2004		2014	
1.	Sweden (0.689), Denmark (0.604), Ireland (0.551), Finland (0.526), Luxembourg (0.428), Slovenia (0.397), Austria (0.350)	I	Sweden (0.820), Denmark (0.688), Lithuania (0.633), Luxembourg (0.623), Finland (0.608), Latvia (0.557), Slovakia (0.512)	I
2.	Hungary (0.348), France (0.341), Czech Republic (0.322), Latvia (0.300), Lithuania (0.294), Estonia (0.294), Cyprus (0.289)	II	Austria (0.478), Slovenia (0.469), France (0.465), United Kingdom (0.445), Ireland (0.410), Poland (0.397), Estonia (0.371)	II
3.	Portugal (0.285), Belgium (0.250), Greece (0.221), United Kingdom (0.216), Netherlands (0.215), Germany (0.202), Malta (0.181)	III	Germany (0.339), Belgium (0.334), Hungary (0.325), Netherlands (0.312), Portugal (0.309), Czech Republic (0.306), Cyprus (0.281)	III
4.	Romania (0.177), Spain (0.125), Croatia (0.108), Italy (0.077), Bulgaria (0.046), Slovakia (0.013), Poland (-0.076)	IV	Romania (0.266), Croatia (0.219), Bulgaria (0.183), Malta (0.105), Italy (0.074), Spain (0.067), Greece (0.026)	IV

Source: author's calculations based on Eurostat data

The worst situation was observed in the case of countries located in Southern Europe. Most of them received worse position in 2014 than in 2004. In the next table (Table 5), the comparison

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of the situation in a geographical region of Europe in 2004 and 2014 was presented.

Table 5

The EU countries sorted by the social and economic development in 2004 and 2014

No	Region	Average position in the ranking	
		2004	2014
1.	Northern Europe	8	7
2.	Western Europe	13	12
3.	Southern Europe	18	22
4.	Eastern Europe	20	18

Source: author's calculations based on Eurostat data

Many authors (Framing…, 2007; Klenert D. et al., 2015; Nic M. and Swieboda P., 2014; Peacock W. G., 1998) indicate that the division of the European Union into 'better' West European countries and 'worse' Eastern Europe, is still synonymous to the differences in the EU development. The results presented in this work show a completely different situation in Europe. According to the results presented, these are so called the new member states located in Eastern Europe that took much higher positions in the compiled ranking than much more developed countries of Southern Europe.

It arises a question: Did the countries of Southern Europe cope so badly with the economic crisis, or whether these changes are associated with a higher resistance to the crisis of countries of Eastern Europe? An answer lies somewhere in the middle. It must be first remembered that in Table 5, there is only information showing what an average position occupies countries located in different geographical regions of Europe. To this average position, e.g. In the case of Eastern European countries in 2014 contributed relatively high positions in Slovakia (group I, 7th place in the ranking) and Poland (group II, 13th place in the ranking) and very low positions of such countries as Bulgaria and Romania (both assigned to the last group with the lowest results). However, in the case of South European countries the relatively high position of Slovenia is observed (group II, 9 position in the ranking) and three lowest places in the created ranking occupied by countries such as Italy, Spain and Greece.

A detailed analysis of positions taken by individual EU countries within the ranking confirms that a significant improvement can be observed especially in the case of countries located in Eastern Europe.

It may be considered whether such a division of Europe into geographical regions describes well the situation of individual EU member states. It should be remembered, however, that the region is e.g. the first indicator considered when choosing the location of the investment (Dunning, 2003, 2004, 2006). In the literature there are many studies showing a region in the context of resistance to a crisis, economic development or development of industrial potential and many others (ex. Stefanescu, 2012). It is one of the most obvious divisions used to describe the socio-economic situation in Europe and in the European Union (in the work considered in the context of sustainable development).

Conclusions

1) The aim of the study results presented in this work was a comparative analysis of changes in the area of sustainable development of the EU before the crisis of 2007-2008 and afterwards.
2) Currently, the worst situation in the field of sustainable development may be found in the countries located in the Southern Europe.
3) Today, the situation in the field of sustainable development in the countries located in Eastern Europe is much better than in the countries located in Southern Europe.
4) The map of divided Europe changed a little after the economic and financial crisis when had turned out that those were the EU countries in the south that suffered most of all.
5) The above observations have been confirmed by the results of the studies and analyses

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presented in this paper. The change of the situation on the level of sustainable development of the EU countries is particularly present in the South European countries. However, the situation has improved in Eastern Europe. Moreover, the West and North European countries have strengthened their position in the rankings measuring the rate of their sustainable development.

6) 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.

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