APPLICATION OF TOPSIS METHOD FOR ANALYSIS OF SUSTAINABLE DEVELOPMENT IN EUROPEAN UNION COUNTRIES

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Abstract

The main purpose of the research is to examine the progress achieved by European countries in the field of implementing the concept of sustainable development and to point the group of countries that can be considered as leaders in that sphere. The research is based on the Eurostat data and it is conducted at macroeconomic level in the years 2004–2013. The sustainable development concept should be considered as a multidimensional phenomenon. Thus, Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was used in the research. TOPSIS method allows to evaluate the objects in terms of multidimensional economic phenomena based on the set of detailed economic attributes (variables). The dynamic synthetic index describing the relative level of sustainable development of the countries was created, which enabled to propose a rating of the countries and group them into homogenous subsets. The grouping was conducted with application of natural breaks method. The comparison of the ratings in the period 2004–2013 shows that most of the new member states of European Union have made a significant progress in implementing the concept of sustainable development. The research enabled to point the countries that are the leaders in the field.

Key words: multiple-criteria decision analysis (MCDA), TOPSIS method, sustainable development, European Union

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Introduction

Creation of conditions for sustainable development is currently a foundation for national policy guidelines in the case of all developed countries. In the European Union it has influenced the main long term development programs such as Lisbon Strategy and Europe 2020 (European Commission, 2010; Balcerzak, 2015). It is a base for priorities in allocation of European Funds. However, macroeconomic policies that support conditions for sustainable

development are not only important form the long term perspective, but they are also crucial from the current and short term point of view, as they influence the most important economic spheres of economic welfare such as regional development (Pietrzak *et al.*, 2014; Wilk *et al*., 2013, Pietrzak & Balcerzak, 2016a), fiscal stability (Balcerzak *et al*, 2016, Balcerzak, Pietrzak & Rogalska, 2016; Balcerzak & Rogalska, 2016), quality of human capital (Balcerzak & Pietrzak, 2016a) and competitive potential in the reality of global knowledge based economy (Balcerzak 2009, 2016; Pietrzak & Łapińska, 2015).

In the case of the EU the main responsibility for realization of sustainable development guidelines is kept at a national level. As a result, there is a need for monitoring progress achieved in this area by all member states. The quantitative methods should be applied in this field. As a result, the main aim of the article is to assess the progress achieved by the EU countries in implementing the concept of socio-economic sustainability and sustainable development and to point the group of countries that can be considered as leaders in that sphere. In the research a macroeconomic perspective is taken in the years 2004-2012. The year 2004 as the first year of the research was chosen deliberately as it was the year of the biggest enlargement of the EU. The last year of the research was mainly restricted with the availability of the Eurostat data.

Based on the literature review and previous work of the authors (Pietrzak & Balcerzak 2016b), it is assumed that the sustainable development is a multidimensional phenomenon that can be only quantified with application of multiple-criteria decision analysis (MCDA) approach. As a result Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was applied in the analysis.

1 Application of TOPSIS for Multiple-criteria Analysis and Economic Research

In spite of the fact that the concept of sustainable development has been the subject of research and scientific discussion for last few years, from the perspective of measurement or even definition, it is still a source of significant controversies (Garriga & Mele, 2004; Bartniczak, 2014; Jurigová & Lencsésová, 2015). However, in the context of its applicability most of economists agree that international comparisons of the level of sustainable development must be done with application of quantitative methods. Then, the concept has strictly multivariate character. Thus, the sustainable development must be analysed with application of multiple-criteria decision analysis (MCDA) methodology (Mardani *et al*.,

2015; Balcerzak & Pietrzak, 2016b, 2016c). As a result, in the proposed research Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is applied.

TOPSIS enables to evaluate the objects in terms of multidimensional economic phenomena based on the set of detailed economic attributes (variables) (Yoon & Hwang, 1995; Balcerzak & Pietrzak, 2016d). Based on a set of diagnostic variables a synthetic index is calculated. Thus, it takes into account the effects of all determinants of multivariate economic phenomenon. In the case of TOSPSIS the synthetic index is defined as the similarity to positive ideal solution and remoteness from the negative ideal solution.

In the case of dynamic research a fixed positive ($I_{s,j}^{P}$) and negative ($I_{s,j}^{N}$) ideal solutions for the whole period of the research should be applied, which is a condition for obtaining comparable results. Then, for every analysed object O_i separation measures $D_{s,i}^{P}$ from the positive ideal solution $D_{s,i}^{P}$ and separation measures from negative ideal solution $D_{s,i}^{N}$ are assessed. Relative closeness to the positive ideal solution is a normalized measure usually on scale of 0-1. The value of synthetic measure of development SMD_i^S that describes every object O_i can be obtained by combining the proximity to the positive ideal solution and the remoteness from the negative ideal solution, given with equation (1).

$$SMD_i^S = \frac{D_{s,i}^{N}}{D_{s,i}^{P} + D_{s,i}^{N}} \tag{1}$$

The value of SMD_i^S describes the level of development of economic phenomena under consideration and the index is also on the scale of 0-1. High value of index SMD_i^S implies high level of development of analysed phenomena for a given object O_i.

2 Quantification of Sustainable Development in the EU Countries with TOPSIS

The aim of the research was the comparison of the level of sustainable development in the EU countries in the years 2004-2013. The analysis was conducted for 24 countries. Malta, Cyprus and Luxemburg were excluded from the research due to unavailability of some data for these economies. Croatia was not included in the analysis either, as the country joined the EU only in the last year 2013. Eurostat data was the base for the conducted study.

As it has been already noted in the previous part of the paper the sustainable development must be treated as multivariate phenomenon. Thus, a set of diagnostic variables (given in Table 1) was used to obtain the synthetic measure of development with application of TOPSIS method with constant ideal solution for the years 2004-2013. This approach

enabled to compare the results from the dynamic perspective. The selection of the diagnostic variables was based on the literature analysis and the proposal of European Commission and Eurostat in regard to variables used for measurement of sustainable development at national level (European Commission, 2010). Table 2 presents descriptive statistics for the diagnostic variables. The variables x_{1t}, x_{2t}, x_{4t} and x_{5t} and x_{8t} can be considered as stimulants, which means that high values of variables support sustainable development. Variables x_{3t}, x_{6t} and x_{7t} were considered as dis-stimulant, which means that high values of variables hamper sustainable development. For the empirical research the dis-stimulants were transferred into stimulants. Then all the variables were normalised with classic normalisation procedure based on average and standard deviation.

Tab. 1: Diagnostic variables used to assess sustainable development in the EU countries

Variable	Description of the variable	Character of the variable
x_{1t}	Socioeconomic development – real GDP per capita	stimulant
x_{2t}	Sustainable production and consumption – resource productivity	stimulant
x_{3t}	Social Inclusion – people at risk of poverty or social exclusion	dis-stimulant
x_{4t}	Demographic changes – employment rate of older workers (aged 55 to 64)	stimulant
x_{5t}	Public Health - healthy life years and life expectancy at birth	stimulant
x_{6t}	Climate change and energy - Primary energy consumption per capita	dis-stimulant
x_{7t}	Sustainable transport - Energy consumption of transport relative to GDP	dis-stimulant
x_{8t}	Global partnership - Official development assistance as share of gross national income	stimulant

Source: own work.

Tab. 2: Descriptive statistics for diagnostic variables

Old EU Member States					New EU Member States				
Variables	Descriptive statistics				Variables	Descriptive statistics			
	M	SD	V	A		M	SD	V	A
x1	31611,43	7503,63	0,24	-0,41	x1	10381,00	3689,75	0,36	0,42
x2	1,86	0,73	0,39	0,51	x2	0,64	0,28	0,43	0,55
x3	21,57	4,70	0,22	0,51	x3	31,67	12,07	0,38	0,59
x4	48,78	10,64	0,22	0,25	x4	42,77	9,34	0,22	0,21
x5	62,58	3,87	0,06	-0,44	x5	59,70	4,71	0,08	0,52
x6	0,12	0,03	0,21	0,84	x6	0,29	0,09	0,31	1,59
x7	93,72	8,20	0,09	0,32	x7	101,87	10,69	0,10	0,22
x8	0,48	0,24	0,50	0,64	x8	0,09	0,02	0,26	-0,17

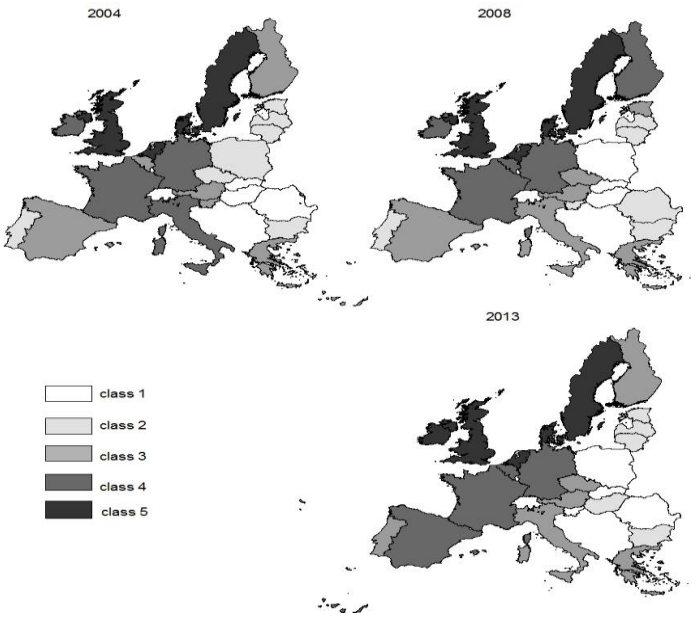
Note: The variables for all the countries under research are characterized with bimodal distribution. It means that descriptive statistics do not have cognitive value in this case. As a result, the countries were divided into two subsets: New and old EU member states. For the two subsets the variables are characterized with unimodal distribution.
Source: own work based on Eurostat data.

In order to obtain a positive ideal solution a maximum value of the variable in the whole period was used. By analogy, in order to obtain a negative ideal solution a minimum value of a given variable for the years 2004-2013 was used. The results for the years 2004, 2008 and 2013 are given in Table 3.

TOPSIS method gives the possibility to order the objects. Additionally, the method allows to divide the objects into homogenous subsets. For this purpose the Jenks method (the method of natural breaks) was used. The idea of the method consists of minimization of variance for objects from the chosen subsets and maximization of variance between the subsets. Application of the method enriches the description of the groups of objects and greatly simplifies the interpretation of the obtained results.

In the research the countries were grouped to five classes, where in the class 5 the economies with the highest level of synthetic measure for sustainable development were grouped. In the class 1 the countries with its lowest value could be found. The classification of the countries is presented in in Figure 1 and Table 1.

Fig. 1: The classification of EU countries from the perspective of sustainable development in the years 2004, 2008 and 2013



Source: own estimation based on Eurostat data.

In the case of the rankings for the years 2004, 2008 and 2013 with the exception of Portugal all the "old" member states occupy the first 13 positions. In the class 5 one can find Denmark, Sweden, the Netherlands and the United Kingdom. All the remaining "old"

members can be found in classes 4 and 3 in chosen years. On the other hand, in classes 2 and 1, which are characterized with the lower values of the measure for sustainable development, one can find "new" members states. In the years 2004-2013 in the class 1, which groups the countries with the lowest level of value of the measure for sustainable development, there are Romania, Hungary, Slovakia, Poland and Slovenia.

Tab. 3: Ranking of EU countries from the perspective of the sustainable development level in the years 2004, 2008 and 2013

Country	*SMD*	*Rank*	*Class*	Country	*SMD*	*Rank*	*Class*	Country	*SMD*	*Rank*	*Class*
Denmark	0,727	1	5	Sweden	0,757	1	5	Sweden	0,721	1	5
Sweden	0,681	2	5	Netherlands	0,657	2	5	Denmark	0,642	2	5
Netherlands	0,668	3	5	United Kingdom	0,644	3	5	United Kingdom	0,642	3	5
United Kingdom	0,637	4	5	Denmark	0,641	4	5	Netherlands	0,637	4	5
France	0,579	5	4	Ireland	0,568	5	4	Ireland	0,611	5	5
Ireland	0,564	6	4	France	0,562	6	4	France	0,563	6	4
Italy	0,531	7	4	Germany	0,552	7	4	Germany	0,560	7	4
Germany	0,525	8	4	Finland	0,518	8	4	Belgium	0,535	8	4
Belgium	0,495	9	3	Belgium	0,514	9	4	Spain	0,509	9	4
Greece	0,490	10	3	Spain	0,492	10	3	Austria	0,479	10	3
Finland	0,483	11	3	Greece	0,479	11	3	Finland	0,469	11	3
Austria	0,458	12	3	Austria	0,461	12	3	Italy	0,454	12	3
Spain	0,457	13	3	Italy	0,460	13	3	Czech Rep.	0,426	13	3
Slovenia	0,415	14	3	Czech Rep.	0,413	14	3	Greece	0,418	14	3
Estonia	0,372	15	2	Estonia	0,403	15	3	Portugal	0,405	15	3
Portugal	0,362	16	2	Portugal	0,366	16	2	Estonia	0,381	16	2
Lithuania	0,352	17	2	Lithuania	0,336	17	2	Lithuania	0,367	17	2
Czech Rep.	0,347	18	2	Bulgaria	0,334	18	2	Latvia	0,326	18	2
Bulgaria	0,341	19	2	Slovenia	0,328	19	2	Hungary	0,324	19	2
Poland	0,319	20	2	Latvia	0,317	20	2	Bulgaria	0,306	20	2
Latvia	0,304	21	2	Romania	0,317	21	2	Slovak Rep	0,293	21	1
Romania	0,292	22	1	Poland	0,253	22	1	Poland	0,275	22	1
Hungary	0,279	23	1	Slovak Rep	0,238	23	1	Slovenia	0,268	23	1
Slovak Rep	0,192	24	1	Hungary	0,222	24	1	Romania	0,203	24	1

Source: own estimation based on Eurostat data.

In the last stage of the research a percentage changes of the value of synthetic measure for the years 2004-2008, 2008-2013 and 2004-2013 were assessed. By analogy to the results presented in Table 3 and Figure 1, the countries were grouped to five classes with application of a natural breaks method. The results are given in Table 4 and Figure 2.

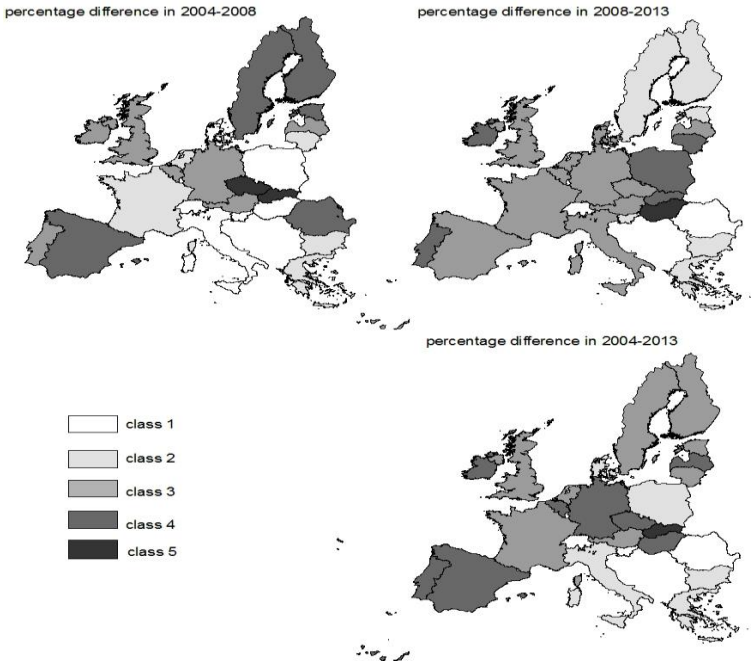
Tab. 4: The changes of the value of synthetic measure for sustainable development for the EU countries

2004-2008				2008-2013				2004-2013			
Country	***% change of SMD***	***Rank***	***Class***	**Country**	***% change of SMD***	***Rank***	***Class***	**Country**	***% change of SMD***	***Rank***	***Class***
Slovak Rep	23,81%	1	5	Hungary	46,36%	1	5	Slovak Rep	52,86%	1	5
Czech Rep.	19,05%	2	5	Slovak Rep	23,47%	2	4	Czech Rep.	22,87%	2	4
Sweden	11,18%	3	4	Portugal	10,46%	3	4	Hungary	16,29%	3	4
Romania	8,60%	4	4	Lithuania	9,04%	4	4	Portugal	11,93%	4	4
Estonia	8,58%	5	4	Poland	8,95%	5	4	Spain	11,31%	5	4
Spain	7,66%	6	4	Ireland	7,68%	6	4	Ireland	8,34%	6	4
Finland	7,20%	7	4	Belgium	4,21%	7	3	Belgium	8,13%	7	4
Germany	5,07%	8	3	Austria	3,74%	8	3	Latvia	7,22%	8	4
Latvia	4,20%	9	3	Spain	3,40%	9	3	Germany	6,67%	9	4
Belgium	3,75%	10	3	Czech Rep.	3,21%	10	3	Sweden	5,87%	10	3
Portugal	1,33%	11	3	Latvia	2,89%	11	3	Austria	4,52%	11	3
United Kingdom	1,25%	12	3	Germany	1,52%	12	3	Lithuania	4,28%	12	3
Austria	0,75%	13	3	France	0,28%	13	3	Estonia	2,56%	13	3
Ireland	0,61%	14	3	Denmark	0,12%	14	3	United Kingdom	0,87%	14	3
Netherlands	-1,62%	15	2	United Kingdom	-0,38%	15	3	France	-2,72%	15	3
Bulgaria	-2,14%	16	2	Italy	-1,39%	16	3	Finland	-2,89%	16	3
Greece	-2,31%	17	2	Netherlands	-3,08%	17	3	Netherlands	-4,65%	17	3
France	-2,99%	18	2	Sweden	-4,78%	18	2	Bulgaria	-10,37%	18	2
Lithuania	-4,37%	19	2	Estonia	-5,54%	19	2	Denmark	-11,69%	19	2
Denmark	-11,80%	20	1	Bulgaria	-8,41%	20	2	Poland	-13,72%	20	2
Italy	-13,37%	21	1	Finland	-9,41%	21	2	Italy	-14,57%	21	2
Hungary	-20,55%	22	1	Greece	-12,56%	22	2	Greece	-14,59%	22	2
Poland	-20,80%	23	1	Slovenia	-18,43%	23	2	Romania	-30,59%	23	1
Slovenia	-20,99%	24	1	Romania	-36,08%	24	1	Slovenia	-35,55%	24	1

Source: own estimation based.

In the case of the "old" members positive changes of the synthetic measure for sustainable development in 2004-2013 occurred in Portugal, Spain, Ireland, Belgium, Germany, Sweden, Austria and the United Kingdom. In spite of the negative consequences of the crisis form the year 2008-2010, in the case of Portugal and Spain the increase of the value of the measure was higher than 10%. The largest decrease in the value of the synthetic measure occurred in Italy and Greece, which amounted 14.57% and 14.59% respectively.

Fig. 2. Percentage change of the value of SMD for sustainable development for the EU countries



Source: own estimation based.

In the case of the Central European countries that joined the EU after 2004, Slovakia, Czech Republic and Hungary can be pointed as the examples of very good results. In the years 2004-2013 these economies recorded the largest increase in the level of the synthetic measure for sustainable development equal to 52.85%, 22.87% and 16.29%. Negative trends occurred during this period in Bulgaria, Poland, Romania and Slovenia. In the case of Romania and Slovenia the value of the synthetic measure decreased by 30%.

This "divergence" among "new" members and relatively good results of such countries as Czech Republic (in relation to other Central European economies the country was relatively highly rated from the first year of the research), or the increase of the value of the measure for such "old" members as Ireland and Belgium, confirm that the improvement of socio-economic sustainability of a country is not only a matter of simple "convergence" process, but it can be seriously influences by institutional and policy factors.

Conclusion

The article concentrated on the problem of sustainable development in Europe analysed form macroeconomic perspective. The aim of the research was to examine the progress achieved by the EU economies in the field of implementing the concept of sustainable development and to

point the group of countries that can be considered as leaders and the example of good practice in the field.

In the paper the sustainable development was treated as a multidimensional phenomenon. As a result TOPSIS method was applied in the analysis. The comparison of the ratings in the years 2004-2013 shows that some of the "new" EU member states have been able to reach a significant progress in supporting the conditions for sustainable development. The research confirms that Scandinavian economies, Netherland and Great Britain can be considered as the leaders in the field.

Additionally, the obtained results can indicate that the improvements of socio-economic sustainability cannot be treated only as a matter of simple "convergence", but this process is rather influenced by institutional and policy determinants.

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