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Technological Potential of European Economy. Proposition of Measurement with Application of Multiple Criteria Decision Analysis

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ABSTRACT

The subject of the research is a technological potential of European Economies at macroeconomic level. The main aim of the article is to assess relative position and eventual progress in that sphere obtained by Central European economies that joined the European Union after the year 2004. Additional goal of the research is to verify usefulness of variables that can be used in measurement of technological potential at macroeconomic level in European economies with application of multiple criteria decision analysis methodology. In the research the phenomenon of technological potential was treated as a multivariate problem. Thus, in order to measure it the multiple criteria decision analysis approach based on the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) was applied. The research was conducted with application of Eurostat Data and diagnostic variables proposed for measurement of technological potential at macro level in European members states. It was done for the years 2008-2012. The applied procedure of verification of information value of potential diagnostic variables enabled to select six final diagnostic variables. The conducted research enabled to point the European leaders, which can be treated as benchmark countries and the source of good practices in the process of forming policy guidelines aiming at supporting technological development. The research showed significant progress obtained by some new European Union members states, which confirms modernization process of Central European economics.

INTRODUCTION

European economy has been quite effective in improving its technological potential and keeping its technological edge for almost whole XX century. However, the global technological transformation related to information technology revolution from the end of previous century has seriously threatened this success (see Bassanini et al. 2000; Bassanini et al., 2001; Balcerzak, 2009). The first European answer to this challenge was the Lisbon Strategy, which was supposed to change European economy into highly competitive sustainable knowledge-based economy (Denis et al, 2005). The improvement of technological potential in the context of global knowledge-based economy is also a fundamental aim of current long term European development plan given in Europe 2020 strategy (see European Commission, 2010, Balcerzak, 2015). In the case of both programs the main responsibility for obtaining their aims belongs to all national governments. As a result, the abilities of European countries to improve their technological potential should be monitored with application of international perspective, which can be useful in finding the examples of best practices. Thus, the main scientific aim of the article is to assess the relative position and progress in that field obtained by Central European economies that joined the EU after the year 2004. Additional, objective of the article is to identify variables that can be used in international measurement of technological potential at macroeconomic level.

The article is a continuation of previous research of the author, where the empirical study of European technological potential was conducted with application of Structural Equation Modeling. In the case of every multiple criteria decision analysis the biggest problem is high sensitivity of final results to changes in methodology of selection of diagnostic variables. In comparison to the previous research in current paper different approach to selection of diagnostic variables was used, which results in different set of final diagnostic variables. Thus, the current analysis, with previous research as a benchmark, can be helpful in assessing stability of results. This analysis of technological potential is a section of research devoted to the role of institutional factors affecting long term growth potential, socio-economic sustainability and economic welfare in the case of highly developed economies (Balcerzak, 2009; Balcerzak & Pietrzak, 2016, Pietrzak & Balcerzak, 2016).

1. THE ECONOMIC ROLE AND DETERMINANTS OF TECHNOLOGICAL POTENTIAL IN GLOBAL KNOWLEDGE-BASED ECONOMY

Technological potential of economy has been the main determinant of growth and welfare of societies since the first industrial revolution. However, the emergence of global knowledge-based economy in recent decades has significantly increased its role both in the case of developed economies and the countries that want to close their development gap. The deindustrialization process experienced by developed economies showed that adopting their technological potential to the new global much more elastic economy is the condition for keeping their high level of welfare. On the other hand, in the case of developing countries quick improvement of technological potential is the only effective strategy, which can help to avoid middle income trap. It has been confirmed by the example of all countries that were able to transfer from underdeveloped economies mostly based on agricultural sector and low income production to developed technological leaders (see: Eichengreen et al. 2012; 2013).

From the macroeconomic perspective the abilities of countries to keep long term growth are mostly determined by their international competitiveness. The role of technological potential in this context is undisputable. Global transformation of world economy has changed this factor into the only long term source of competitive advantage. A decrease of transportation and telecommunication costs, an increase of mobility of traditional economic resources have led to an increased competition in the case of standard industrial products, which must go in hand with a decrease of profit margins available for their suppliers. In this context only suppliers of technologically advanced goods, where knowledge is the main and difficult to substitute production factor, are able to reach high value added (OECD, 1996; 2001; 2002). It means that macroeconomic technological potential of a country is currently the main determinant of abilities to take advantage of international trade. Current literature devoted to the influence of international trade on growth creation confirms that dominant role in international trade is attributed to the exchange of technologically advanced and knowledge-based products among the countries that are characterized by relatively close technological level. High value added is mostly reached in intra-industry trade in the case of technologically advanced economies (Pietrzak & Łapińska, 2015; Łapińska, 2016; Stefaniak-Kopoboru & Kuczewska 2016).

The technological potential of a county is a factor significantly affecting position of enterprises at microeconomic level. It supports or hampers technological possibilities of local companies, which affects their competitive position in global supply chains. In the case of bigger companies with international potential operating in technologically advanced environment, high technological potential of a country increases their chances to become multinationals. In the case of smaller firms, it can improve their positions in cooperation with international partners. Lack of technological advance forces local firms to operate as suppliers of standard goods or resources, which are currently easily to replace. On the other hand, high technological potential in a specific technological niche enables even small and medium sized enterprises to become long term partners for global players, which can support their growth potential. It means that the globalized economy can be the source of potential benefits even for small and medium sized enterprises, but only under condition that they are able to provide knowledge-based process or product (Cieślik et al., 2014; Wagner, 2011).

In this context the question on the determinants of countries technological potential and the ways to close the development gap in this sphere is still the core of empirical research and policy discussions. The analysis of political disputes or national and international strategies in the case of developed economies can often lead to a simplified conclusion that the most important factor is just obtaining a given level of R&D expenditure in an economy. As an example in the Lisbon Strategy the aim was set at 3% of GDP. In the end it has become the synonym of the whole plan. When there is a problem with obtaining assumed level of investments, significant role of governments in this sphere is usually pointed. On the other hand, in the case of developing countries the question on the reasonability of investments of scarce national resources into R&D activity is often asked. The market-oriented economists reluctant to national strategies, which could lead to increasing investments in R&D, often tend to argue that in the case of countries that are not technological leaders relatively ineffective national R&D expenditures can be substituted by adopting existing technologies and encouraging foreign direct investments. In that context it is often argued that the whole process should be left to the market mechanism. However, current literature indicates that both points of view must be treated as serious simplifications. High technological potential cannot be neither build nor kept by simple reaching a given level of R&D expenditure or strategies concentrating on importing existing technologies (Piech, 2007; Witkowski, 2007). It cannot be simply build or improved just by direct operational actions of government. However, the experiences of successful macroeconomic modernizations also confirm that pure market mechanism is also not effective in this sphere.

From the macroeconomic perspective high level of technological potential is the result of multivariate factors and long term strategies implemented at macro, regional and microeconomic level that increase effectiveness of national innovation system of a country (Kondratiuk-Nierodzińska, 2016). These factors start with long term institutional policy increasing entrepreneurship and competitive intensity, building effective national research and development sector, supporting the process of knowledge diffusion among enterprises and encouraging absorption of new technology and knowledge from abroad (Nelson, R. R. (Ed.), 1993; Chung, 2002; Piech (Ed.) 2007; Atkinson and Correa, 2007; Atkinson and Nager 2014). As a result there is a great need for international comparative research that can be useful in pointing the leaders and best practices in that field, which can be useful for building or evaluating strategies of national technological modernization.

2. SELECTION OF POTENTIAL DIAGNOSTIC VARIABLES AND VERIFICATION OF THEIR INFORMATION IMPORTANCE

As it has been already stated in the introduction the biggest weakness of every multiple criteria analysis is relatively high sensitivity of final results to the changes in the process of section and verification of final diagnostic variables. As a result, the selection process should be always based on two steps: first of all, the preliminary selection of potential diagnostic variables, which is based on the experience of a researcher and literature review of previous research in the field. This step is mostly influenced by subjective factors. Then, in the second step formal objective (quantitative) criteria should be applied for selection of final diagnostic variables (Gostkowski, 1972). In current research both elements were introduced.

The preliminary set of diagnostic variables was chosen based on the availability of data gathered by Eurostat for measuring of technological potential in the the EU economy, which was supported by previous research of the author (Balcerzak, 2009, 2016) and literature review of the factors determining the macroeconomic technological potential in the reality of knowledge-based economy (David & Goddard Lopez, 2001; Cichy, 2009; Libertowska, 2014; Madrak-Grochowska, 2015). The proposed set of preliminary variables can be characterized as output measures of technological potential of economies (Piech, 2007, p. 29). As a result a set containing seven preliminary variables suggested by Eurostat was selected for the research.

Table 1. Set of preliminary diagnostic variables proposed by Eurostat for measuring technological potential of countries

Variable	Description of Variables
X_1	Total intramural R&D expenditure (GERD) (euro per inhabitant)
X_2	Share of government budget appropriations or outlays on research and development (% of total general government expenditure)
X_3	High tech export (% of total export)
X_4	Human resources in science and technology (% of active population)
X_5	Patent applications to the European patent office (EPO) by priority year (per 1 million inhabitants)
X_6	Turnover from innovation (% of total turnover)
X_7	Total R&D personnel (per 1 million inhabitants)

Source: own work.

In the second step a formal verification of variables information value was conducted with application of taxonomic criteria of information value (Zeliaś (Ed.), 2000, pp. 127-133, Hellwig, 1972, pp. 69-90). Based on this approach, it is assumed that the final diagnostic variables should fulfill three formal criteria:

a) High level of variation – the diagnostic variables should not be similar to each other in the sense of information on the objects. To evaluate the level of variation, the coefficient of variation is usually used. In that case the variables, which do not fulfill a formal criterion for example such as $\varepsilon < 0{,}1$, should be eliminated.
b) High information value – the variables should reach high values with relatively great difficulty. To evaluate the information values of the variables the skewness coefficient is usually applied. In the case of stimulants the demanded distribution of the variable should be right-skewed. When it is left-skewed, it means that most of the objects relatively easily reach high values of the measure for a taken factor, and it does not differentiate the objects significantly. In that case the variable should be excluded from the research.
c) Low level of correlation – the diagnostic variables should not be highly correlated. High corre-

lation of the variables results in overlapping of information. For highly correlated diagnostic variables a Hellwig's parametric method can be used, where the maximum acceptable value of correlation coefficient for potential variables can be given as r = 0,8 (Hellwig, 1972, pp. 69-90).

In the case of current research only variable X_1 has not fulfilled the above criteria. As a result it has been removed from the set of final diagnostic variables. For comparison in previous research with application of SEM methodology the variables X_6 and X_7 were excluded from the final model (see Balcerzak and Pietrzak, 2016a). The last step of data preparation process was normalization of variables. All the final diagnostic variables were treated as stimulants (the higher value of the variable means that given factor improves the technological potential of the country). Thus, they were only standardized with application of classic standardization procedure. It enables to obtain variables characterized with mean at the level 0 and variance that is equal to 1. It is given with equation 1.

$$x_{ijt} := \frac{x_{ijt} - \overline{x_{jt}}}{s_{jt}} \qquad i = 1,2,..n,\ j = 1,2,...,p,\ t = 1,2,..l \tag{1}$$

where $\overline{x_{jt}}$ and s_{jt} are given with formulas 2.

$$\overline{x_{jt}} = \frac{1}{n}\sum_{i=1}^{n} x_{ijt}\ ,\quad s_{jt} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_{ijt} - \overline{x_{ijt}})^2} \qquad i = 1,2,..n,\ j = 1,2,...,p,\ t = 1,2,..l \tag{2}$$

3. APPLICATION OF TOPSIS FOR MULTIPLE CRITERIA ANALYSIS OF TECHNOLOGICAL POTENTIAL

As it was pointed in second section of the article technological potential of economies analysed form macroeconomic perspective should be considered as complex phenomenon. Thus, in the case of international comparative studies it can be measured with application of multiple criteria analysis methodology (Mościbrodzka, 2014; Jurkowska, 2014; Mardani, et al., 2015, 2016; Jantoń-Drozdowska & Majewska, 2016; Łyszczarz, 2016). In the article application of Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is proposed for analysis of 24 European countries in the years 2008-2012. The period of the analysis was mainly restricted by availability of data for the whole panel of countries. Croatia was not included in the analysis, as it entered the European Union in 2013. Luxemburg, Malta and Cyprus were also excluded from the research due to small sizes and very specific factors concerning these economies.

TOPSIS method allows to assess the objects O_i (in that case the European Union countries) in terms of multidimensional phenomenon based on the set of specific economic diagnostic variables (Yoon & Hwang, 1995). As a result, it is possible to calculate a synthetic indexed SI_i^s, which can be used for ordering and building rankings of analysed countries. The synthetic index is calculated as a similarity to positive ideal solution $(I_{s,j}^P)$, which can be defined as maximum value of a given variable, and remoteness from a negative ideal solution $(I_{s,j}^N)$, which is usually defined as minimum value of a given variable. In order to conduct dynamic research fixed positive and negative ideal solutions for the whole research period must be applied. This approach enables to obtain comparable results in time (Balcerzak & Pietrzak, 2016).

In order to obtain synthetic index for every analysed object O_i separation measures from the positive ideal solution $D_{s,i}^P$ and separation measures from negative ideal solution $D_{s,i}^N$ are calculated. The value of synthetic index is obtained by combining the proximity to the positive ideal solution and the remoteness from the negative ideal solution, which is described with equation (3) (Balcerzak & Pietrzak, 2016).

$$SI_i^s = \frac{D_{s,i}^N}{D_{s,i}^P + D_{s,i}^N} \quad (3)$$

The SI_i^s is a normalised measure on the scale of 0-1. Its high values imply high level of development of analysed phenomena for a given object O_i. More detailed description of TOPSIS method is available in Balcerzak & Pietrzak (2016).

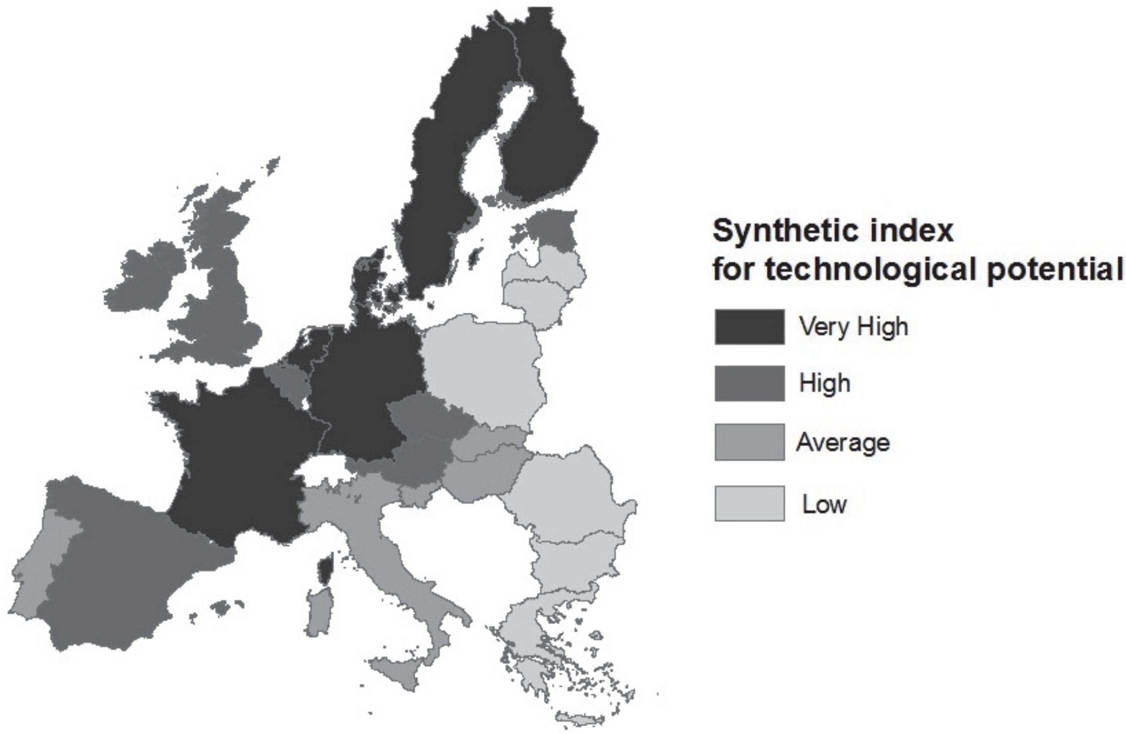
The ratings of countries obtained after application of the described procedure are available in table 2. It presents the values of the synthetic index for the years 2008-2012 and its average value in the whole period. Then, the average value of the obtained index was used for grouping the countries into four relatively homogenous subsets. For this purpose natural breaks method was applied. In the case of the method variance for objects from the chosen subsets is minimised and variance between the subsets is maximised (Jenks, 1967; Balcerzak & Pietrzak (2016). The results are given in Figure 1.

Table 2. Results of TOPSIS analysis of technological potential

No	2008		2009		2010		2011		2012		2008-2012	
1	FI	0,7747	FI	0,7358	FI	0,6944	DK	0,6771	DK	0,6851	FI	0,6983
2	DE	0,6828	DE	0,6814	DK	0,6637	DE	0,6568	DE	0,6614	DE	0,6687
3	DK	0,6301	DK	0,6651	DE	0,6613	FI	0,6553	NL	0,6599	DK	0,6642
4	SE	0,5944	SE	0,6020	SE	0,6101	NL	0,6257	FI	0,6315	SE	0,5959
5	FR	0,5671	FR	0,5630	NL	0,5854	SE	0,5890	FR	0,6058	NL	0,5947
6	NL	0,5462	NL	0,5565	AT	0,5658	FR	0,5835	UK	0,5907	FR	0,5756
7	CZ	0,5205	AT	0,5346	FR	0,5587	AT	0,5558	SE	0,5841	AT	0,5481
8	AT	0,5152	CZ	0,5083	ES	0,4994	UK	0,5168	AT	0,5691	CZ	0,5038
9	IE	0,5134	ES	0,5013	BE	0,4987	EE	0,5142	IE	0,5100	IE	0,4934
20	ES	0,4942	IE	0,4938	CZ	0,4921	CZ	0,4975	EE	0,5049	UK	0,4907
11	SI	0,4589	BE	0,4732	EE	0,4908	IE	0,4951	CZ	0,5004	ES	0,4802
12	HU	0,4542	UK	0,4541	UK	0,4548	BE	0,4851	BE	0,4934	BE	0,4799
13	PT	0,4500	HU	0,4510	IE	0,4545	ES	0,4719	SK	0,4505	EE	0,4765
14	BE	0,4489	SI	0,4455	SK	0,4487	SK	0,4657	ES	0,4341	SI	0,4288
15	UK	0,4369	EE	0,4397	HU	0,4286	PT	0,4217	PT	0,4228	PT	0,4280
16	EE	0,4328	PT	0,4316	PT	0,4140	SI	0,4205	SI	0,4184	HU	0,4215
17	IT	0,3591	SK	0,4007	SI	0,4010	HU	0,4066	HU	0,3673	SK	0,4190
18	LT	0,3482	IT	0,3763	IT	0,3917	IT	0,3670	IT	0,3456	IT	0,3679
19	SK	0,3292	LT	0,3173	LT	0,3121	LT	0,3038	LT	0,3068	LT	0,3176
20	BG	0,2916	RO	0,2788	RO	0,2829	GR	0,2782	GR	0,3020	GR	0,2749
21	RO	0,2884	GR	0,2619	GR	0,2661	RO	0,2157	PL	0,2300	RO	0,2367
22	GR	0,2665	BG	0,2532	PL	0,2375	PL	0,2117	LV	0,2200	PL	0,2193
23	LV	0,2322	PL	0,2152	BG	0,2062	LV	0,1956	BG	0,1377	BG	0,2130
24	PL	0,2023	LV	0,2025	LV	0,1927	BG	0,1763	RO	0,1174	LV	0,2086

Source: own estimation based on Eurostat data.

Figure 1. Grouping of countries based on average value of synthetic index for the year 2008-2012 with application of natural breaks method



Source: own work.

The results presented in table 2 and on figure 1 to high extant correspond to the outcomes of research applying multiple criteria analysis tools for classification of countries based on their abilities to use potential of knowledge-based economy, which is related to their technological potential (Żelazny, 2015; Dutta et al., 2015; Hollanders et al., 2015; Balcerzak, 2015; 2016; Skrodzka, 2016).

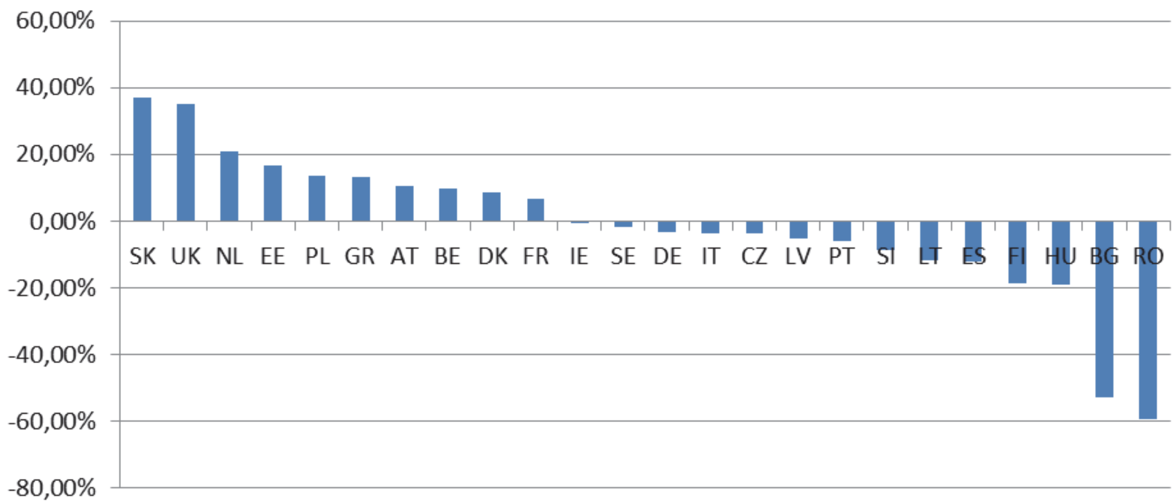
It can be seen that Scandinavian countries with Germany, Netherlands and France can be considered as technological European leaders. Then one can find old member countries of the European Union. The ranking is closed with the new member states.

When one concentrates on the results obtained by new members states good positions obtained by Czech Republic and Estonia should be especially stressed. These two economies can be found in the same group as Austria, Ireland and United Kingdom. The results can suggest that these two economies can compete technologically with developed European countries, which is the condition for escaping middle income trap.

In the context of discussion on the role of institutional factors influencing speed of technological modernisation form the second section of this article, it is also worth to refer to good results of Estonia and Czech Republic in the process of reforming their institutional systems for global knowledge-based economy. Multiple criteria analysis of quality of institutions in the European Union countries in the context of global knowledge-based economy confirmed that Estonia is unquestionable leader among the new member states and Czech Republic was pointed as an example of good institutional reforms in the years 2000-2013 (Balcerzak and Pietrzak, 2016).

Finally, the dynamics of the synthetic measure in the years 2008-2012 was calculated, which is presented on figure 2.

Figure 2. Dynamics of synthetic index of technological potential for EU countries in the years 2008-2012



Source: own estimation.

In relation to the improvement of the synthetic measure of technological potential in the years 2008-2012 among the leaders one can find Slovakia, Estonia, Poland and Greece. These countries cannot be considered as technological European leaders. As a result, they can relatively easily improve their positions by transferring effective technological solutions from highly developed economies. However, among the countries that improved their results in the analysed years, one can also find such economies like: United Kingdom, Netherlands, Belgium, Denmark and France, which can be placed at European technological frontier. On the other hand, such countries like Bulgaria or Romania recorded negative dynamics of the measure of technological potential. It means that the speed of their eventual improvements is lower than the one implemented by the rest of analysed economies. Therefore, the noticeable increase of the measure of technological potential in Slovakia, Estonia, Poland cannot be only treated as an effect of low statistical base. The conducted research confirms that the changes of technological potential can be significantly affected by policy and institutional factors, which is consistent with the theoretical discussion in second section of the article. The specific determinants of success in that sphere should be considered as an important area of continuation of this study and future research in the field.

CONCLUSION

The objective of the research was to conduct international comparative analysis of technological potential in the European Union countries. The technological potential was treated here as multivariate phenomenon. Therefore, the multiple criteria decision analysis, specifically TOPSIS method, was applied here. The main aim of the paper was to assess the situation in Central European economies. Additionally, the article enabled to verify usefulness of variables suggested by Eurostat for measurement of technological potential at macroeconomic level.

In the case of new member states one can point Czech Republic and Estonia as the leaders in the field. The specific actions and modernization programs implemented by the governments of these countries should be the subject of special interests for other decision-makers in the region. The conducted research confirms that the variables provided by Eurostat for comparative international analysis can be effectively used for measurement of technological potential at macroeconomic level.

The empirical research indicates that improving technological potential of economies, especially in the case of the countries that should close their technological gap, cannot be easily explained by the low base statistical effect. It is influenced by both effective policy and institutional factors.

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