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RANKING OF EUROPEAN UNION MEMBER STATES BASED ON THE LEVEL OF KNOWLEDGE CREATED BY THE RESEARCH AND DEVELOPMENT SECTOR

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A b s t r a c t

The contemporary era is characterized by revolutionary changes in the economy, technological progress, social and political life. Globalization exerts pressure on businesses and entire economies to increase their competitive strength which is defined as the ability to create knowledge. Knowledge creation and management became the new management paradigms. The responsibility for knowledge creation rests mainly upon the research and development sector. The aim of this study was to rank European Union Member States based on the level of knowledge created by their respective research and development sectors and to identify knowledge creation leaders. The analysis relied on EUROSTAT data for 2007–2011 and linear ranking methods with a reference standard. Our results indicate that Western European and Scandinavian countries are the leaders in the area of knowledge creation.

CHARAKTERYSTYKA WSPÓLNOTY EUROPEJSKIEJ ZE WZGLĘDU NA KREOWANIE WIEDZY W WYNIKU DZIAŁALNOŚCI BADAWCZO-ROZWOJOWEJ

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S ł o w a k l u c z o w e: wiedza, GOW, działalność B+R, metoda porządkowania liniowego ze wzorcem, Unia Europejska.

A b s t r a k t

Współczesność cechuje duża turbulentność otoczenia ekonomicznego, technologicznego, społecznego i politycznego. Zjawisko globalizacji dodatkowo potęguje presję wywieraną na przedsiębiorstwa oraz całe gospodarki do zwiększania ich konkurencyjności, za której fundament przyjmuje się uniejętność kreowania wiedzy. Tworzenie oraz wykorzystywanie wiedzy stało się

nowym paradygmatem zarządzania. Odpowiedzialność w tym zakresie spoczywa głównie na sektorze B+R. Celem artykułu jest próba charakterystyki Unii Europejskiej uwzględniającej identyfikację krajów Wspólnoty będących liderami w kreowaniu wiedzy w wyniku prowadzenia działań w sferze badawczo-rozwojowej. Do analiz wykorzystano dane statystyczne EUROSTAT z lat 2007–2011 oraz metodę porządkowania liniowego ze wzorcem. Wyniki badań wykazały, że największy udział w kreowaniu wiedzy mają kraje Europy Zachodniej oraz państwa skandynawskie.

Introduction

In the last decade of the 20th century, the concept of a knowledge-based economy became a fundamental determinant of microeconomic and macroeconomic development. The term "knowledge-based economy" (KBE) was coined in the 1990s by the OECD to imply an economy which is directly based on the production, distribution and use of knowledge and information (The knowledge – based economy 1996). At the time, there existed a general belief that the convergence of knowledge, information and computer technology would be the main driver for economic growth, wealth creation and employment in all market segments. The new century marked the beginning of Toffer's Third Wave Society, a concept that envisaged the birth of a knowledge-based economy where the predominance of knowledge would act as a substitute for the remaining resources (TOFFLER 1986, pp. 34–35). A knowledge-based economy became the leading trend in the international community of the 21st century, and most countries shifted their focus to the creation of a supportive environment for technological innovation (The knowledge – based economy, 2006). One of the first people to develop this concept was Peter Drucker who argued that knowledge would be the principal economic resource in the coming decades, and "knowledge workers", namely well-educated employees, would form the leading social group. Drucker referred to this period as the era of "knowledge society" (DRUCKER 1999, pp. 13–19). This concept has enjoyed soaring popularity in the past years because it enables businesses and economies to maintain their competitive advantage, and it enhances the effectiveness of innovative technologies (LIN et al., 2007, pp. 22–39). The knowledge management concept is increasingly likely to determine a company's performance (GRANT 1996, pp. 109–122). The rate of knowledge acquisition, creation and processing and knowledge building skills are the driving force for success in business and economy. In line with the discussed concept, knowledge became an object of interest in various scientific disciplines, including management science.

The objective of knowledge management is to amalgamate the richness of experience (discovering new production techniques and problem solving methods through experimentation) while maintaining clarity of action and exercising control over knowledge (JAYAWARNA, HOLT 2009, pp. 775–785).

In modern economies, knowledge is created mainly through research and development (R&D). Pursuant to the provisions of the Lisbon Strategy of 2000, whose goals have not been fully achieved, and the Europe 2020 strategy, the EU Member States, including Poland, are expected to invest in knowledge creation and "intelligent growth" based on knowledge and innovation.

The aim of this study was to rank European Union Member States based on the level of knowledge created by their respective research and development sectors and to identify knowledge creation leaders. It was assumed that the analysis would identify differences between the EU Member States rather than European regions.

Materials and Methods

The levels of knowledge created by research and development institutions in the EU Member States were analyzed based on EUROSTAT data for 2007–2011. Data for Greece covered the last four years of the analyzed period. The analyzed objects were classified by a linear ranking method with a reference standard. The diagnostic variables were: research and development spending (% GDP), share of government budget appropriations on research and development (% of total government expenditure) and employment in the R&D sector. All diagnostic variables were stimulants of knowledge creation. The choice of variables was determined by the availability of statistical data.

In the linear ranking approach, objects are classified based on a single attribute. The ranked objects are assigned numbers from 1 to n. A set of n objects is ranked by determining the sequence of objects in that set according to a set criterion, from the best (number 1) to the worst (number n) (Perkal in: BALICKI 2009, p. 317). Although objects are ordered based on a single parameter, linear ranking methods support an analysis of multidimensional objects. To add other dimensions to the classification process, a composite statistic is required, and the Human Development Index is generally used as a function of variation in a set of attributes. Z. Hellwig proposed a composite measure of development which involves a hypothetical reference for determining the distance from real points. The reference (an ideal and abstract object) is characterized by the best values of diagnostic variables reported for all objects (HELLWIG 1968). Those variables can be further classified as stimulant (positive variables), destimulant (negative variables) and nominant (neutral variables).

There are many methods of developing composite measures of development. This study relies on the method proposed by Hellwig (TARCZYŃSKI 2002, pp. 94–98). The first stage involved the construction of a two-dimensional

matrix X containing observations of diagnostic variables for the analyzed objects:

$$X = \lfloor x_{ij} \rfloor \quad (i = 1,..., n; j = 1,..., m) \tag{1}$$

where:
X – matrix of observations of variables describing the analyzed objects (countries),
N, m – number of objects, number of variables.

In the second stage, the elements of matrix X were standardized using the below formula:

$$x_{ij} = \frac{x_{ij} - \bar{x}}{S_j} \tag{2}$$

where:
$\bar{x}$ – arithmetic mean for the j-th variable,
Sj – standard deviation for the j-th variable

$$S_j = \sqrt{\frac{\sum_{i=1}^{n} (x_{ij} - \bar{x})^2}{n - 1}} \tag{3}$$

After standardization, matrix X was transformed into matrix Z with elements z_{ij}. The reference object was developed based on the elements of matrix Z. The highest value was selected from each column of matrix Z, producing a reference object (reference country) with the best coordinates observed in reality:

$$z_{01}, z_{02}, ..., z_{0m}; z_{0m} = \max\{z_{ij}\} \tag{4}$$

The distance separating each country from the reference was calculated. Various distance measures have been proposed in literature (e.g. BALICKI 2009 p. 317). In this study, the Euclidean distance was used:

$$d_j = \sqrt{\frac{\sum_{i=1}^{m} (x_{ij} - z_{oj})^2}{m}} \quad (i = 1, 2,..., n) \tag{3}$$

A synthetic variable expressed by formula (5) is not normalized, which could obstruct the analysis. The below formula can be used to achieve normalization and create a scenario where higher values of the variable testify to higher levels of knowledge creation (ŁUNIEWSKA 2005 p. 470):

$$z_i = 1 - \frac{d_i}{d_0} \quad (i = 1, 2,..., n) \tag{6}$$

where:

z_i – composite measure of development for the i-th object,

d_i – distance between the i-th object and the reference determined according to (5)

d_0 – standard which guarantees that the value of zi falls in the range of 0 to 1.

Results

The values of the composite measure of development are presented in Table 1. The composite measure of development objectifies a given country's ranking in the knowledge creation hierarchy. It can assume values in the range of [0,1]. In the surveyed years, a relatively high level of knowledge created by R&D units was determined in France, Germany, Finland and Sweden (the composite measure of development exceeded 0.5 in each country). The performance of the United Kingdom, which ranked at number five, was weakened only in 2011 when the value of the measure of composite development fell to 0.4984. In Denmark, the level of created knowledge was marked by continued improvement.

In 2007 and 2008, the measure of composite development attained average values, and it continued to grow in the following years to exceed the 0.5 threshold by 0.0086 in 2009, by 0.0582 in 2010 and by 0.0851 in 2011. The countries characterized by the highest values of the composite measure of development are global leaders as regards their competitive advantage. In the Global Competitiveness Report for 2010–2011, Sweden, Finland and Germany ranked 4th, 6th and 7th, respectively (World Economic Forum, 2011). Sweden has the highest level of informatization in the world. The remaining economies became highly competitive due to substantial expenditures for research and development with the State's involvement. Poland ranks far behind the ranking leaders. In 2007–2008, the value of the composite measure of development for Poland was seven times lower in comparison with the ranking leader. Despite a significant increase in spending on research and development, Poland continued to lag behind other EU countries in successive years of the

Table 1
Composite measure of development as a reflection on R&D activities in the EU Member States

Country	Year				
	2007	2008	2009	2010	2011
France	0.6273	0.5954	0.6116	0.6040	0.6237
Germany	0.6263	0.6277	0.6707	0.6794	0.6630
Finland	0.5910	0.6048	0.6028	0.6086	0.6399
Sweden	0.5629	0.5702	0.5476	0.5647	0.5920
United Kingdom	0.5317	0.5250	0.5537	0.5223	0.4984
Denmark	0.4415	0.4565	0.5086	0.5582	0.5851
Netherlands	0.4050	0.4182	0.4151	0.4015	0.4054
Austria	0.3979	0.4079	0.4399	0.4777	0.4964
Spain	0.3505	0.3970	0.4362	0.4448	0.4297
Belgium	0.3375	0.3673	0.3909	0.4109	0.3974
Italy	0.3001	0.3010	0.3442	0.3594	0.3469
Luxembourg	0.2745	0.3021	0.3394	0.3571	0.3810
Czech Republic	0.2648	0.3023	0.3305	0.3172	0.3264
Slovenia	0.2591	0.2790	0.2889	0.3039	0.3847
Ireland	0.2500	0.2481	0.2706	0.2822	0.3112
Portugal	0.1799	0.2236	0.2768	0.3589	0.3863
Estonia	0.1733	0.2308	0.2386	0.2674	0.2786
Lithuania	0.1484	0.1497	0.1707	0.1214	0.1021
Hungary	0.1194	0.1158	0.1377	0.1592	0.1852
Greece	0.0998	(*)	(*)	(*)	(*)
Poland	0.0896	0.0922	0.1105	0.1008	0.1057
Slovakia	0.0634	0.0717	0.0587	0.0851	0.0737
Bulgaria	0.0496	0.0691	0.0487	0.0727	0.0816
Romania	0.0212	0.0654	0.0841	0.0956	0.0340
Latvia	0.0190	0.0736	0.0910	0.0776	0.0023
Cyprus	0.0096	0.0235	0.0633	0.0553	0.0616
Malta	0.0000	0.0000	0.0000	0.0000	0.0000

(*) - data not available.
Source: own study based on EUROSTAT data.

analysis. The value of the composite measure of development was six times lower in 2009 and 2011 and more than 6.5 times lower in 2010 in comparison with the corresponding ranking leaders.

A ranking of the EU Member States was developed based on the corresponding values of the composite measure of development (Table 2). In 2007–2011, France, Germany and Finland were ranking leaders who occupied the first three places in varied sequence. Germany is the unquestioned leader

Table 2

Ranking of the EU Member States based on the composite measure of development

Country	Year				
	2007	2008	2009	2010	2011
France	1	3	2	3	3
Germany	2	1	1	1	1
Finland	3	2	3	2	2
Sweden	4	4	5	4	4
United Kingdom	5	5	4	6	6
Denmark	6	6	6	5	5
Netherlands	7	7	9	10	9
Austria	8	8	7	7	7
Spain	9	9	8	8	8
Belgium	10	10	10	9	10
Italy	11	13	11	11	14
Luxembourg	12	12	12	13	13
Czech Republic	13	11	13	14	15
Slovenia	14	14	14	15	12
Ireland	15	15	16	16	16
Portugal	16	17	15	12	11
Estonia	17	16	17	17	17
Lithuania	18	18	18	19	20
Hungary	19	19	19	18	18
Greece	20	20	21	(*)	(*)
Poland	21	21	20	20	19
Slovakia	22	23	25	22	22
Bulgaria	23	24	26	24	21
Romania	24	25	23	21	24
Latvia	25	22	22	23	25
Cyprus	26	26	24	25	23
Malta	27	27	27	26	26

(*) – data not available.
Source: own study based on EUROSTAT data.

in knowledge creation. It is one of the most developed countries in the world, and the German economy ranks third after the USA and Japan. Its economic growth is strongly rooted in industrial development, mostly motor, mechanical engineering, electrical engineering and chemical sectors. Germany specializes in complex investment products and innovative production technologies. Germany was followed by Finland, which ranked second on three occasions, and France which came third in the course of three years. Finland was transformed

from a largely agrarian economy to a modern economy in the course of several decades. One of the goals of the Finnish industrial policy is to integrate industrial growth with research and development. The above gave rise to integrated industries which are linked by technological, production and R&D ties (STACHOWIAK 2009, p. 129).

Sweden and United Kingdom also play a pivotal role in knowledge creation. Similarly to the top three leaders, they swapped places in successive years of the ranking. The above indicates that ranking leaders continued to be the key creators of knowledge in R&D units throughout the analyzed period. The group of top 10 countries also included Denmark, Netherlands, Austria, Spain and Belgium. In comparison with 2007, the lowest level of knowledge creation was noted in Malta, which occupied the last place in the ranking throughout the surveyed period, followed by Cyprus, Latvia, Romania and Bulgaria. The majority of the weakest performers were the youngest EU Member States. Poland ranked 21st in the first year of the study, and it continued to improve its performance every two years to reach number 19 in 2011. This is not a satisfactory result, and it will hopefully be improved in the future.

The relationship between the values of the composite measure of development in the surveyed years was analyzed with the use of the correlation coefficient. Statistical dependency between variables was determined by Spearman's rank correlation (Table 3).

Both measures point to a very strong correlation between the studied phenomena. For this reason, national policy makers should focus on the creation of knowledge through increased spending on research and development.

Table 3
Correlations between the value of the composite measure of development and position in the ranking of the EU Member States

Coefficient	Year			
	2007/08	2008/09	2009/10	2010/11
Pearson's correlation coefficient	0.9949	0.9947	0.9918	0.9904
Spearman's rank correlation coefficient	0.9915	0.9872	0.9869	0.9829

Source: own study based on EUROSTAT data.

The creation of knowledge through increased spending on research and development should be the key focus of both business managers and national policy makers. The awareness that knowledge creation plays a key role in building and strengthening the competitive advantage of the Member States and the entire EU in the global arena should be translated into action, and this

goal has been addressed by the Europe 2020 strategy. Pro-innovative measures which support knowledge creation are also initiated in Poland. In efforts to strengthen its competitive advantage, Poland should support the development of the high-tech sector and intellectual capital. In the mid 1990s, this path of development was adopted by Finland which had faced similar economic and political challenges as Poland. The pursuit of the above goals requires further reform of the educational system, increased spending on research and development and the introduction of new measures encouraging businesses to invest in innovation, including research commercialization and integration of business and R&D communities by increasing the profitability of innovation investments.

Conclusions

The linear ranking method with a reference standard was used to rank the level of knowledge created by research and development organizations of the EU Member States. The countries that invested most heavily in knowledge creation were France, Germany and Finland. Portugal's ranking continued to improve throughout the analyzed years. The value of its composite measure of development increased from 0.1799 in 2007 to 0.3863 in 2011, and Portugal climbed six notches from the 17th to the 11th place. Austria's performance also improved, but the noted changes were less spectacular than in Portugal. Austria's composite measure of development increased from 0.3979 in 2007 to 0.4964 in 2011. Cyprus and Malta lagged far behind other EU countries, and Malta ranked last throughout the surveyed period.

With the exception of Portugal and Austria, knowledge creation trends remained unchanged in the analyzed years. The best performers continued to remain in the lead, while the countries with average and low levels of knowledge creation occupied the same or insignificantly changed positions in the ranking. Western European and Scandinavian countries emerged as leaders in the area of knowledge generation. The lowest levels of knowledge creation were reported in selected countries of Southern Europe, whereas average and low levels were noted in Central and Eastern Europe.

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