Composite Indicators in Regional Comparison of Science and Technology

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Abstract

Afforded achievement of the scientific and the technological areas is one of the determinant conditions that increase the competitiveness and productivity of economy. Accordingly, the promotion of research and development activity has vital priority in the development policy. However, some issues come up: How are S&T input and output divided among the territorial units? Is it possible to put the regions in a definite order on the basis of S&T activities? Does center-periphery relationship exist in S&T sector as we get used to it in other areas of economy? In the first part of my study we will introduce different composite indicators in the area of S&T based on international and Hungarian professional literature. In the second part we will examine the S&T activities of the Hungarian regions, separating the absolute and relative indicators which describe the research and development in different classes. After making known the results of the comparative analysis, we will create complex indices with the help of the principal components analysis (PCA), set out from both the absolute and relative indicators. By this, it will be possible to put the Hungarian regions in an unambiguous order on the basis of their S&T activities.

Key words: Science and technology, composite indicators

JEL Classification: O32

1 Introduction

Afforded achievement of the scientific and the technological areas is one of the determinant conditions that increase the competitiveness and productivity of economy. Accordingly, the promotion of research and development activity has vital priority in the development policy of Hungary. However, some issues come up: How are R&D input and output divided among the country's territorial units? Is it possible to put the regions in a definite order on the basis of R&D activities? Does center-periphery relationship exist in R&D sector as we get used to it in other areas of economy?

In the first part of my study I will examine the R&D activities of the Hungarian regions, separating the absolute and relative indicators which describe the research and development in different classes. After making known the results of the comparative analysis, I will create complex indices with the help of the principal components analysis (PCA), set out from both the absolute and relative indicators. By this, it will be possible to put the Hungarian regions in an unambiguous order on the basis of their R&D activities.

2 Composite indicators

An increasing interest is shown from both the political decision-makers and the public opinion regarding the complex indices that compare the performance of the countries. The indices that allow comparing the countries in an easy way are suitable for demonstrating the very complex and elusive fields, like technological development, innovation and research and development. It is easier to inform the public opinion with these indicators than finding a common trend from lots of single indices and they are proved to be useful in the benchmarking countries' performance. Complex indices can send a misleading political message at the same time if they were created in a wrong way or misunderstood. The image shown by the indices often forces the users especially the political decision-makers to make simplistic analytical or political conclusions, instead of having the composite indicators as keynotes and arouse interest in the publicity. Their suitability can only be evaluated by the fields affected [1].

2.1 Summary Innovation Index

The Summary Innovation Index (SII) is the composite indicator of the aggregated national innovation performance that consists thirty indices from the European Innovation Scoreboard (EIS). In the first step they count a so called Dimension Composite Innovation Index (DCII) for all the seven subgroups (human resources, finance and support, firm investments, linkages and entrepreneurship, throughputs, innovators and economic effects), which is the unweighted mean of transformed values of variables concerning the certain subgroups. In the second step they determine a so called Block Composite Innovation Index (BCII) for all the three groups (enablers, firm activities and outputs), which is the unweighted mean of the transformed values of variables concerning the certain groups. In the third step they create the summarized innovation index, which is the unweighted mean of the transformed values of all the thirty indices. According to the summarized innovation index they aggregate the companies into four groups (innovation leaders, innovation followers, moderate innovators and catching-up countries) with the help of the hierarchical cluster analysis based on the summarized innovation index [2], [3].

2.2 Global Innovation Scoreboard Index

They count a so called dimension composite innovation index for all the three dimension of the Global Innovation Scoreboard (GIS), which is the arithmetic mean of indicators concerning the given dimensions. The Global Innovation Scoreboard Index (GIS Index) consists there Dimension Composite Innovation Indices (DCII). Since the innovation scoreboard emphasizes the innovation activity of the companies, the first dimension ("firm activities and outputs") take part in the creation of GIS Index with 40 percent weight, while the other two dimension ("human resources" and "infrastructure and absorptive capacity") with 30-30 percents. On the basis of the Global Innovation Scoreboard Index and also with the help of the hierarchical cluster analysis they aggregate the countries into four groups (complete linkage between groups) [4].

2.3 Revealed Regional Summary Innovation Index

The composite indicator of the Regional Innovation Scoreboard (RIS) is the Revealed Regional Summary Index, (RRSII) which identifies the leader regions according to the relative innovation performance in the European Union and in certain countries as well.

According to the last method the RRSII is the weighted mean of the Regional National Summary Innovation Index (RNSII), and the Regional European Summary Innovation Index (REUSII) [5]. In the firs step they subject the RNSII and the REUSII indices to transformation, before using them for counting the RRSII index. In the second step they determine the RRSII index, which is the weighted mean of the transformed indices of the RNSII and the REUSII.

2.4 Technological Advance Index

Technological-Advance Index (Tech-Adv) is one of those two indicators, which creates Industrial-cum-Technological-Advance Index (ITA). ITA is contained by the Industrial Development Report of the United Nations Industrial Development Organization (UNIDO). The origins of the index are two sub-indices: Industrial-Advance Index (Ind-Adv) and Tech-Adv. The Tech-Adv sub-indicator is defined as the arithmetic mean of the share of the medium- and high-tech added value industry on the total added value, and on the total of manufacturing exports. The previous one reflects the concentrate degree of the productive structure of the countries in the medium-tech and high-tech industries while the last one expresses the competitiveness of the national economic structures in the markets of the developed sectors [6].

2.5 Technology Activity Index

The Technological Activity Index (TAI) is one of those two indicators, which create the Innovation Capability Index (UNICI). The United Nations Conference on Trade and Development (UNCTAD) developed UNICI and publicizes it in the World Investment Report. The index is the arithmetical mean of the two sub indices: TAI and Human Capital Index (HCI). This measures the technological activity using both input and output measures, respectively represented by labor force employed in R&D related activities, and the amount of patents and scientific publications [7].

2.6 ArCo Technology Index

ArCo Technology Index (ArCoTi) is a composite indicator, which considers the variables connected with three dimensions of technological development. The first one is the innovation activity of the economic system of the countries which it expresses with the numbers of the patents and the scientific articles. The second dimension contains the spread of the old and new technologies (internet penetration, telephone penetration, electricity consumption), while the third dimension consists the development of human skills. ArCoTI is the arithmetic mean of the three sub indices which are also the arithmetic means of the variables that create them [8].

2.7 Index of the World Economic Forum

The twelfth leg of Global Competitiveness Index (GCI) developed by the experts of the World Economic Forum (WEF) is an innovation index, which contains seven variables: capacity of innovation, quality of scientific research institutions, company spending on R&D, University-industry research collaboration, government procurement of advanced technology products, availability of scientists and engineers, utility patents [9].

2.8 Index of the World Bank

The Knowledge Economy Index (KEI) developed by the employees of World Bank (WB) and the third leg of Knowledge Index (KI) are also innovation indices which include royalty and license fees payments and receipts as input variables and patent applications granted by the USPTO, scientific and technical journal articles as output variables. These indices are available in absolute value and per capita as well [10].

2.9 Principal Component Analysis

Borsi and Telcs [11], [12] tried to get an answer if there can be constructed a composite indicator for the understandable groups of R&D statistics therefore it explains an adequately large part from standard deviation of the indices. They answered the question with Principal Component Analysis (PCA) [13]. According to their statement with the help of this method the set up composite ranks that consider more indices can be interpreted well.

2.10 Genetic Algorithm

Borsi and Telcs [11] tried to get an answer if there can be created an unperemptory weighting between research and development indices with which a statistically consistent rank can be created. They gave an answer with one of the popular heuristic optimum searching solution: Genetic Algorithm (GA) and they stated that a concrete position can be defined onto the countries analyzed with the help of the method.

2.11 Fuzzy Set Theory

The Fuzzy Set Theory (FST) that is often applied in the fields of management sciences [14] [15], [16], [17] was first used by Moon and Lee [18] to make composite science and technology indices. The science and technological indices analyzed were assigned according to secondary and primary research then they asked the experts of different fields (academic sector, civil sector, industry, natural sciences and social sciences) to give their opinion on the relative significance of the indicators with the help of attributes. From the indicators – weighting the experts' answers with the particular value with the help of the Fuzzy Set Theory – they created three composite indicators: "R&D input" (R&D personnel, R&D expenditure, and R&D stock), "R&D output" (patent, paper, technology trade) and "economic output" which were applied for cross section and longitudinal analysis.

2.12 Data Envelopment Analysis

Borsi [24], [12] used the Data Envelopment Analysis (DEA) in the Hungarian professional literature [19], [20], [21], [22], [23] for the first time for analyzing R&D efficiency based on Färe et al [25]. However in the international professional literature [1] this field of application is not new. In the data envelopment analysis they used the R&D expenditures and the R&D workers as inputs and the numbers of publications and patents as an output. The data envelopment analysis calculates those points in the multi dimensional space which represent the countries performing the best. The points determine the curve of the efficiency potentials. The countries below the curve are not effective; at the same time from the efficiency indices of those countries that can be found near them the position of the ineffective countries can be assigned.

2.13 Other indices

Organizations like International Institute for Management and Development (IMD), the National Scientific Board, RAND, and the United Nations Development Programme (UNDP) tried to measure the R&D and innovation performance of the countries with composite indicators. However these attempts were only for one year and did not go on [26], [27], [28], [29], [30]. We would like to mention the attempts which were made to measure especially the R&D activity of the industrial and service sectors [31], the creativity which serves as a basis for research and development activity [32], [33] and economic globalization [34].

3 Territorial ranks

The research and development activities of the Hungarian regions can be described with either absolute or relative indicators. I observe that the application of various indicators give opportunities for different explanation. According to Borsi-Telcs [11], the absolute indicators represent the counties as "weighted points" on the map of Hungarian R&D, whereas the relative indicators describe certain "competitiveness" and "effectiveness". Furthermore, the absolute and relative statistics lead to different territorial ranks, therefore I will discuss the absolute and relative indicators in different parts of my study.

3.1 Territorial ranks by absolute indicators

There are different input and output indicators to feature the R&D performance and the most important are reachable by territorial units in the statistical reviews so it makes the research and development activity in the Hungarian counties (NUTS III.) and regions (NUTS II.) comparable.

Table 1: Absolute indicators of research and development, 2007

	Number of R&D units	Total R&D calculated staff number	Expenditure, million HUF	Research themes and developing tasks	Scientific publications
Central Hungary	1 374	16 252	158 761	13 681	22 497
Central Transdanubia	186	1 417	12 916	1 358	1 450
Western Transdanubia	216	1 246	14 819	1 900	2 058
Southern Transdanubia	246	1 066	6 072	1 198	2 990
Northern Hungary	173	1 155	8 373	1 815	2 278
Northern Great Plain	335	2 417	20 446	2 303	4 246
Southern Great Plain	310	2 401	18 983	2 426	3 428
Total	2 840	25 954	240 371	24 681	38 947

Source: KSH [35]

- R&D units are those places, where research and development are done as primary or secondary activity under national, educational or corporative bounds [36]. On the first place we can find Central Hungary with its 1 374 units which makes up 48% of the whole. The next one is Northern Great Plain (335 R&D units) and Southern Great Plain (310 R&D units). There are another two regions with more than 200 units in each: Southern Transdanubia and Western Transdanubia.

- Total R&D calculated staff number is the number of employed in R&D sector reflected to the full time jobs [36]. On the first place there is Central Hungary again with 16 252 researchers, 63% of the whole. The second is Northern Hungary (2 417 researchers) and then comes Southern Great Plain (2 401 researchers).
- The most important statistic of research and development activity is the expenditure of R&D units, or with other words sum of currents and capital expenditure coming from national or international sources as well [36]. Budapest and Pest county has the main dominance in this field as well, 65% of the expenditures are used here: In Central Hungary therefore in 2007 more than 158 billion HUF were spent on research and development while in Northern Great Plain it was more than 20 billion HUF, in Southern Great Plain it was about 19 billion HUF.
- Total number of research themes and developing tasks are registered goals at R&D units which tend to make new possible scientific-technological results [36]. Two years ago in Central Hungary there were 13 681 research themes, 55% of the whole. On the second place there was Southern Great Plain (2 426 research themes), and the third was Northern Great Plain (2 303 research themes).
- Total numbers of scientific publications are the written works of the researchers written either in Hungarian or in a foreign language: books, chapters, studies, and articles in learned journals [36]. The first place of Central Hungary is essential: there were 22 497 publications in 2007, 58% of the whole. The second is Northern Great Plain (4 246 publications) again and then Southern Great Plain (3 428 publications).

3.2 Territorial ranks by relative indicators

The comparison of the Hungarian regions is possible not only by absolute but relative indicators based on ranks as well. However these indicators are not available at the Hungarian statistical yearbooks, they can be determined by background calculations.

Table 2: Relative indicators of research and development, 2007

	R&D persons per capita	Expenditure as a percentage of GDP	Expenditure per R&D person, million HUF	Scientific publications per capita	Scientific publications per R&D person
Central Hungary	**0,0056**	**0,0141**	**9,7687**	**0,0078**	**1,3843**
Central Transdanubia	**0,0013**	**0,0055**	**9,1153**	**0,0013**	**1,0233**
Western Transdanubia	**0,0012**	**0,0063**	**11,8933**	**0,0021**	**1,6517**
Southern Transdanubia	**0,0011**	**0,0039**	**5,6964**	**0,0031**	**2,8049**
Northern Hungary	**0,0009**	**0,0044**	**7,2492**	**0,0018**	**1,9723**
Northern Great Plain	**0,0016**	**0,0090**	**8,4592**	**0,0028**	**1,7567**
Southern Great Plain	**0,0018**	**0,0090**	**7,9063**	**0,0026**	**1,4277**
Total	**0,0026**	**0,0103**	**9,4665**	**0,0039**	**1,5006**

Source: KSH [35], [37]

- In the aspect of researchers per capita Central Hungary is the very first with its 5.6‰. This situation in Southern Great Plain is much worse, there are only 1.8 full time researchers per 1000 person. It is even worst in Northern Great Plain (1.6‰) but it is still in the top.
- Expenditure as a percentage of GDP is also a good indicator of the R&D competitiveness of the regions. Maybe it is not a surprise that Central Hungary is the first again with

1.41%. The next one is Southern Great Plain (0.90%) and than comes Northern Great Plain (0.90%).

- In the aspect of number of scientific publications per capita Central Hungary is the first with again 7.8 publications per capita in 2007. The other regions' "productivity" is less, like Southern Transdanubia (3.1‰) and Northern Great Plain (2.8‰). The front-rankers are followed by Southern Great Plain with two per mille of arrears. The other regions' lags can be considered much more serious.
- The situation is completely different with the number of scientific publications per researcher. On the first place there is Southern Transdanubia, with 2.8 publications per researcher in 2007. The researchers have eminent results in Northern Hungary (2.0), Northern Great Plain (1.8) and Western Transdanubia (1.7). Central Hungary in this rank has only the sixth place.
- In the area of expenditure per researcher Western Transdanubia is in the best position with its 11.89 million HUF. In this aspect Central Hungary's arrears is minimal, because they spent 9.76 million HUF in 2007. Central Transdanubia has only subtle arrears from this sum, where a researcher – in a figurative sense – could manage 9.11 million HUF.

4 Territorial rank-optimization with principal component analysis

It is unambiguously clear from the analysis of county ranks, based on absolute and relative indicators, that the more indicators exist, the more ranks can be set up for describing the research and development activities of the Hungarian regions. After that, it seems a reasonable object to create a complex index, which contains the most possible pieces of information about the examined indicators. In other words, a complex index can explain the largest possible part from the standard deviation of the indicators.

The previous task can be solved with principal component analysis, which is a special case of the explorative factor analysis [38]. Its primary purpose is the reduction of dimension number, in other words the reduction of variables, so that the least possible information can be lost about the statistical population and same conclusions can be made at the same time [39].

As the description of the R&D activity gives chance for analyzing absolute and relative indicators, it is worth completing the principal component analysis for both groups. I will explain the results accordingly on absolute indicators at first and then on relative ones as well.

4.1 Optimal territorial rank based on absolute indicators

The absolute indicators, which describe the R&D activities of the Hungarian regions, are strongly correlated with each other, as the value of KMO (0.799) is middling and the hypothesis of the Bartlett's test of sphericity had to be rejected, too (Sig. 0.000).

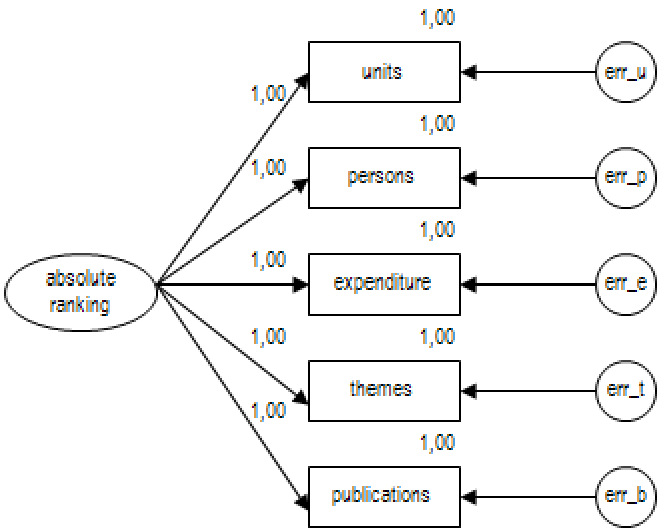

Figure 1: Principal component analysis of formed orders based on absolute indicators
Source: Compiled by author

The eigenvalue of the first principal component is 4.987, in other words, the 99.732% of the information kept by the five absolute indicators was successfully compressed in one variable. The simple linear correlation coefficients (factor weights) between the principal component and the absolute indicators are very large, all the five of it approaches one (numbers on the left arrows) just like the extraction communalities of the original variables (numbers above the right upper corner of the rectangles). All these mean that the absolute indicators used in the analysis count for a lot approximately the same weight at the creation of the principal component.

The principal component produced by this way corresponds to a complex index, with the help of which unambiguous rank can be formed on the basis of the R&D weight of the Hungarian regions. Indisputably, Central Hungary stands in the first place, as it was the first through all the absolute indicators. Northern Hungary takes the possession of the second place, and Southern Great Plain is the third. Western Transdanubia and Southern Transdanubia are right in the middle places of the regions. Northern Hungary and Central Transdanubia can be characterized with the smallest R&D weight.

4.2 Optimal territorial rank based on relative indicators

The correlation of relative indicators, which describes R&D activities, is unacceptable on the basis of KMO value (0.358), but according to the Bartlett's test of sphericity (Sig. 0.000) the original variables are not independent, so the principal component analysis has existence.

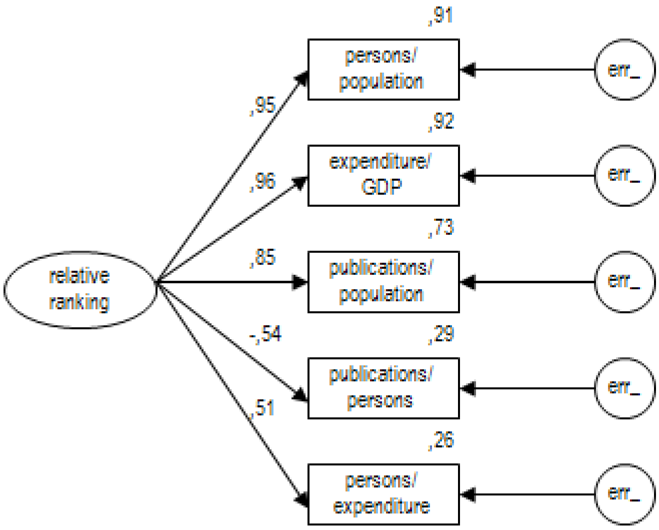

Figure 2: Principal component analysis of formed orders based on relative indicators

Source: Compiled by author

The value of the first principal component calculated with relative indicators is 3.113, namely the 62.266% of information, which is brought through original variables, was successfully compressed in one principal component. The factor weights except for the "scientific publications per researcher" and "expenditure per R&D persons" (0.51-0.54) are very high (0.85-0.96) also at this case, just like the last communalities of the relatives indexes (0.73-0.92), from among which the "scientific publications per researcher" and "expenditure per R&D persons" (0.26-0.29) are the odd one out, too. Consequently, these variables take part in the creation of the principal component of R&D "effectiveness" and "productivity" with lower weight than the other variables.

The complex index created by relative indicators defines an unambiguous rank among the regions in this case, too. The first place of Central Hungary is no longer a question. Southern Great Plain stands in the second place and Northern Great Plain stands in the third. The following regions are right in the middle place: Western Transdanubia and Central Transdanubia. Northern Hungary and Southern Transdanubia have the largest lagging on the areas of the R&D "effectiveness" and "productivity".

5 Conclusions

In what follows, I will summarize the most important results and conclusions of my analysis, which is connected with the R&D activities of the Hungarian regions.

- As a summary it can be told, that the quantitative and qualitative measuring methods of the separate indices can be observed as facts. With the help of them the relative position of the countries can be determined in a specific area and the spatial or temporal direction of change can be assigned. Furthermore the indicators are useful in order to determined trends, to arouse attention in connection with a topic, to set up political priorities, and the benchmarking or monitoring of performance. We talk about composite indicators, when separate indices create a single index on the basis of a mathematic or calculation model. The composite indicator is able to measure such multidimensional concepts which cannot catch separate indices [1]. The most important advantages of the composite indicators: they are able to sum up complex or multidimensional topics, they give an image of given topic, it is easier to interpret than to find a common trend in many separate indices, they facilitate the ranking of the countries, help with catching the attention of the public opinion, summarize the performance of the countries and their temporal changes, they decrease the extension of the index lists, contain more information. Disadvantages: they can send misleading political information if they are created badly or misunderstood. They can be useless if their structure is unclear and based on incorrect statistic principals. Politics can influence the selection of the sub-indices and weights. The demand is increasing for making sub-indices and statistic significance analysis [40].

- Analyzing the absolute indicators of research and development (R&D units, total R&D calculated staff number, expenditure in R&D units, Total number of research themes and developing tasks, total number of scientific publications), there is no doubt about the first place of Central Hungary, however the further sequence changes from indicator to indicator.
- In the case of the relative indicators (researchers per capita, R&D expenditure as a percentage of GDP, number of scientific publications per capita, number of scientific publications per researcher, expenditure per researcher) the situation is very similar with one exception: the number of scientific publications per capita Central Hungary stand only in the end of the rank.
- The principal component analysis is very good for condensing the absolute indicators into one complex index, without any important loss of information (0.268%). Then an opportunity is offered to line up the Hungarian regions by their R&D weights: 1. Central Hungary, 2. Northern Great Plain, 3. Southern Great Plain.
- For the reduction of data, the principal analysis can also be applied in the case of relative indicators, although here the loss of information (37.74%) can be considered more serious. The final rank on the areas of "effectiveness", "productivity" principal component of the R&D is obvious as well: 1. Central Hungary, 2. Southern Great Plain, 3. Northern Great Plain.

References

[1] NARDO, M., SAISANA, M., SALTELLI, A., TARANTOLA, S., HOFFMAN, A., GIOVANNINI, E.: *Handbook on Constructing Composite Indicators – Methodology and User Guide*. Paris, Organisation for Economic Co-operation and Development, 2005.

[2] HOLLANDERS, H., VAN CRUYSEN, A.: *Rethinking the European Innovation Scoreboard – A New Methodology for 2008-2010*. Brussels, Pro Inno Europe/Inno Metrics, 2008.

[3] EUROPEAN COMMISSION: *European Innovation Scoreboard*. Brussels, 2009.

[4] ARCHIBUGI, D., DENNI, M., FILIPPETTI, A.: *Global Innovation Scoreboard 2008*. Brussels, Pro Inno Europe/Inno Metrics, 2009.

[5] HOLLANDERS, H.: *Regional Innovation Scoreboard 2006*. Brussels, Pro Inno Europe/Inno Metrics, 2007.

[6] UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION: *Industrial Development Report 2005.* Vienna, 2005.

[7] UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT: *World Investment Report 2005*. New York, 2005.

[8] ARCHIBUGI, D., COCO, A.: A New Indicator of Technological Capabilities for Developed and Developing Countries (ArCo). In: *World Development*. Vol. 32, No. 4 (2004), pp. 629-654.

[9] WORLD ECONOMIC FORUM: *The Global Competitiveness Report 2008-2009.* Geneva, 2008.

[10] WORLD BANK: *World Development Indicators 2009*. Washington, 2009.

[11] BORSI B., TELCS A.: A K+F-tevékenység nemzetközi összehasonlítása ország-statisztikák alapján. In: *Közgazdasági Szemle*. Vol. 51, No. 2 (2004), pp. 153-172.

[12] TÖRÖK Á.: *Competitiveness in Research and Development – Comparisons and Performance*. Cheltenham, Edward Elgar Publishing, 2005.

[13] NIWA, F., TOMIZAWA, H.: *Composite Indicators – International Comparison of Overall Strengths in Science and Technology*. Tokyo, National Institute of Science and Technology Policy, 1995.

[14] TRAN, L. T., KNIGHT, C. G., O'NEILL, R. V., SMITH, E. R., RIITTERS, K. H., WICKHAM, J.: Fuzzy Decision Analysis for Integrated Environmental Vulnerability Assessment of the Mid-Atlantic Region. In: *Environmental Management*. Vol. 29, No. 6 (2002), pp. 845-859.

[15] TSAUR, S. H., CHANG, T. Y., YEN, C. H.: The Evaluation of Airline Service Quality by Fuzzy MCDM. In: *Tourism Management*. Vol. 23, No. 2 (2002), pp. 107-115.

[16] MOON, J. H., KANG, C. S.: Use of Fuzzy Set Theory in the Aggregation of Expert Judgments. In: *Annals of Nuclear Energy*. Vol. 26, No. 1 (1999), pp. 461-469.

[17] SOHN, K. Y., YANG, J. W., KANG, C. S.: Assimilation of Public Opinions in Nuclear Decision-making Using Risk Perception. In: *Annals of Nuclear Energy*. Vol. 28, No. 6 (2001), pp. 553-563.

[18] MOON, H.S., LEE, J. D.: A Fuzzy Set Theory Approach to National Composite S&T Indices. In: *Scientometrics.* Vol. 64, No. 1 (2005), pp. 67-83.

[19] BUNKÓCZI L., PITLIK L.: *A DEA (Data Envelopment Analysis) módszer falhasználási lehetőségei üzemhatékonyságok méréséhez*. Debrecen, Agrárinformatika, 1999.

[20] FÜLÖP J., TEMESI J.: A Data Envelopment Analysis (DEA) alkalmazása ipari parkok hatékonyságának vizsgálatára. In: *Szigma.* Vol. 32, No. 3-4. (2001), pp. 85-109.

[21] KOTY, L.: A gazdasági hatékonyság számítása DEA lineáris programmal. In: *Statisztikai Szemle*. Vol. 75, No. 6 (1997), pp. 515-524.

[22] TIBENSZKYNÉ F. K.: Az oktatás hatékonyságának mérése a ZMNE 2006-ban végzett hallgatóin Data Envelopment Analysis (DEA) módszer használatával. In: *Hadmérnök*. Vol. 2, No. 2 (2007), pp. 149-165.

[23] TÓTH, Á.: *Kísérlet a hatékonyság empirikus elemzésére*. Budapest Magyar Nemzeti Bank, 1999.

[24] BORSI B.: *Tudás, technológia és a magyar versenyképesség*, Budapest, Ph.D. értekezés, 2005.

[25] FÄRE, R., GROSSKOPF, S., KNOX LOVELL, C.A.: *Production Frontiers*. Cambridge, Cambridge University Press, 1994.

[26] INTERNATIONAL INSTITUTE FOR MANAGEMENT AND DEVELOPMENT: *World Competitiveness Yearbook 2009*. Lausanne, 2009.

[27] WAGNER C. S., BRAHMAKULAM, I., JACKSON, B., WONG, A., YODA, T.: *Science and Technology Collaboration – Building Capacity in Developing Countries*. Santa Monica, RAND, 2001.

[28] WAGNER C. S., HORLINGS, E., DUTTA, A.: *Can Science and Technology Capacity be Measured?* Santa Monica, RAND, 2001.

[29] NATIONAL SCIENCE BOARD: *Science and Engineering Indicators 2008*. Arlington, 2008.

[30] UNITED NATIONS DEVELOPMENT PROGRAMME: *Human Development Report 2007/2008*. New York, 2007

[31] HOLLANDERS, H., KANERVA, M.: *Service Sector Innovation – Measuring Innovation Performance for 2004 and 2006 Using Sector Specific Innovation Indexes*. Brussels, Pro Inno Europe/Inno Metrics, 2009.

[32] HOLLANDERS, H., VAN CRUYSEN, A.: *Design, Creativity and Innovation – A Scoreboard Approach*. Brussels, Pro Inno Europe/Inno Metrics, 2008.

[33] HUI, D., NG, C., MOK, P., FONG, N., CHIN, W., YUEN, C.: *A Study on Creativity Index*. Hong Kong Home Affairs Bureau, The Hong Kong Special Administrative Region Government, 2005.

[34] ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT: *Measuring Globalization – OECD Handbook on Economic Globalisation Indicators 2005*. Paris, 2005.

[35] KÖZPONTI STATISZTIKAI HIVATAL: *Kutatás és fejlesztés*. Budapest, 2008.

[36] KÖZPONTI STATISZTIKAI HIVATAL: *A K+F statisztika módszertana*. Budapest, 2004.

[37] KÖZPONTI STATISZTIKAI HIVATAL: *Magyar statisztikai évkönyv*. Budapest, 2008.

[38] HAJDU O.: *Többváltozós statisztikai számítások.* Budapest, KSH, 2003.

[39] KETSKEMÉTY L., IZSÓ L.: *Bevezetés az SPSS programrendszerbe.* Budapest, ELTE Eötvös Kiadó, 2005.

[40] SAISANA, M., TARANTOLA, S.: *State-of-the-art Report on Current Methodologies and Practices for Composite Indicator Development*. Ispa, Joint Research Centre, 2002.