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Benchmarking Methodologies Used for Comparative Analysis of Scientific and Educational Systems on the Example of Central and Eastern European Countries

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Abstract: Basing on the known methodologies of territorial benchmarking (EIS-, GCI- and KA-methodologies), there has been built a series of Education, Research and Innovation Scoreboards for Central and Eastern European countries, using simulation calculations. Aggregating integral indicators across all the constructed scoreboards into one complex index by means of the Polish taxonomy method has allowed doing the mapping of CEEC. There has been outlined a tendency of growing educational and innovative potential of countries when moving westwards.

Key words: Benchmarking methodology · Scientific and education systems · European Innovation Scoreboard · Global Competitiveness Index · Knowledge Assessment Methodology · Geographic Information System · Polish taxonomy · Mapping · Central and Eastern European countries

INTRODUCTION

Benchmarking methodologies have been used in various spheres of human activities since the 1980s and have been studied in detail [1, 2]. The present article looks at the three benchmarking methodologies used for comparative analysis of innovative development and competitiveness of countries:

- The European Innovation Scoreboard [3],
- The Global Competitiveness Index of countries [4]
- Knowledge-Assessment methodology [5].

All these will be adapted to be further used for comparative analysis of the scientific and educational systems on the example of Central and Eastern European countries (CEEC).

Within the framework of the first methodology, for the countries under study we will select the values of indicators of research and educational activities and a Research and Education Scoreboard will be constructed as a result. We will show how one can use it to carry out simulations aimed at reaching the target features of the more advanced countries. This is inherent in benchmarking, but unfortunately has not been used among the analytical techniques of the European Innovation Scoreboard so far.

Within the framework of the second methodology, we will also select the values of indicators showing the education and innovation activities of CEEC and will construct Education and Innovation Scoreboards. To do so, we will be borrowing the procedures of calculating standardized and integral indicators from the EIS-methodology. As in the first case, we will be giving examples of simulations at the end.

Within the framework of the third methodology, we will construct Education and Research Scoreboards for the countries under study in two variants: based on Knowledge Assessment-methodology and EIS-methodology.

The separate Education, Research and Innovation Scoreboards constructed within the two latter methodologies, will be aggregated in three general scoreboards. The three aggregated indicators resulting

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from them, along with the integral indicator of the EIS-methodology, will be aggregated again by means of the method of Polish taxonomy to calculate a complex indicator. The latter will be used for mapping CEEC.

The European Innovation Scoreboard for Comparing Scientific and Educational Systems of CEEC: The European Innovation Scoreboard (EIS), as the main benchmarking instrument of the Lisbon strategy of the European Commission, was launched in 2001. It included 17 innovation indicators for the EU Member states as well as two countries used for comparison - the USA and Japan, all indicators being divided into four big groups. EIS was of universal character and when creating it, the EIS experts tried to select the maximum of indicators describing the variety of innovative performance aspects of the courtiers. Later versions of EIS included even a bigger number of indicators. When selecting them, experts would always face a problem of their comparability because different countries would maintain different records of these indicators. The European Council experts considered EIS as a territorial benchmarking procedure.

In 2010, EIS was reworked and renamed as the Innovation Union Scoreboard (IUS), which draws on 25 special research and innovation-related indicators, divided into three big groups: Enablers, Firm Activities and Outputs. In turn, the first big group has been divided into smaller subgroups: Human Resources, Open, Excellent and Attractive Research Systems and Finance and support. The second big group includes such subgroups as Firm Investment, Linkage and Entrepreneurship and intellectual assets and the third group covers Innovators and economic effects.

Out of 25 special indicators, we have selected those connected with the functioning of university systems (Table 1). The inclusion of Indicator 2.1.1. onto the list can be explained by the fact that entrepreneurial expenses on R&D can be partly directed to support the links between the university and the industry.

The definitions of Indicators 1.1.1.-1.1.3 include the UNESCO international classification (1997) (Table 2).

For Table 2, in relation to the definitions of Indicators 1.1.1-1.1.3 (Table 1) we need to provide the following explanation. Programmes ISCED 3A of the third level are designed to provide direct access to academic programmes of the fifth level (ISCED 5A), while programmes ISCED 3B are aimed at providing direct access to practically-oriented programmes for obtaining specific professions of the fifth level (ISCED 5B). Programmes ISCED 3C of the third level are not designed for direct access to programmes ISCED 5A and 5B, but rather are oriented towards the labour market or professional training programmes of the fourth level. Now that we have clarified all the selected S&E indicators, let us construct a Research and Education Scoreboard for Central and Eastern European countries, using IUS 2010 (Table 3).

First, we will create a matrix of values of primary relative and specific indicators *(I_{ij})* with dimension $n \times m$, where I_{ij} is the value of a i^{th} indicator for a j^{th} country, $1 \leq i \leq 11$, where $n = 11$, which is the number of indicators, $1 \leq j \leq 16$, where m=16, which is the number of Central and Eastern European countries. This matrix includes the average values of each indicator for all EU27 (Table 3), the data being taken from IUS 2010.

The integral indicator for each country will be constructed as the arithmetic mean of standardized values of individual (primary relative and specific) indicators in the same way it is done for IUS:

$$I_j = \frac{1}{n}\sum_{i=1}^{n}(I_{ij} / I_{iave}) \qquad (1)$$

The values of this integral indicator are shown in Table 3.

Table 4 includes the interpretation of the abbreviations of CEEC.

As the computed values of the integral indicator I_j show, the leading nations according to this indicator are Switzerland, Austria, Germany and Slovenia, whose indicator values are above the average for EU 27; while the outsiders are the Former Yugoslav Republic of Macedonia, Romania, Latvia and Bulgaria. To make a more rigorous classification of the countries according to their S&E potential, we introduce the following six-level uniform classification scale and place along it all the CEEC under study (Table 5).

As we can see, the majority of CEEC are at very low and low levels of development of their S&E potential. Having created the Research and Education Scoreboard for CEEC, we can construct various scenarios to improve the positions of the lagging countries. For instance, we can see that the Research and Education potential of the Czech Republic (I_2=0.69) is twice as low as that of Germany (I_3 =1.46). Supposing that within the next three years, the Czech Republic were planning to dramatically increase enrolment of Master’s and PhD students (the latter being from outside EU27), bringing the values of indicators 1.1.2 and 1.2.3 up to the average European levels, the value of indicator 1.1.1 reaching the German level. Then, having recalculated indicator I_2, we would get

Table 1: Selected IUS 2010 Indicators Used to Construct the Research and Educational Scoreboard

IUS 2010 selected indicators	Definition	Source	Notes
Human resources 1.1.1. New doctorate graduates	Number of PhD graduates (PhD course, ISCED6) per 1000 population aged 25-34	Eurostat	EIS 2009 additionally used the indicator of the number of S&E è SSH graduates per 1000 population aged 20-29
1.1.2. Population having completed tertiary education	Percentage population aged 30-34 having completed a higher education (ISCED 5 и 6)	Eurostat	EIS 2009 embraced a broader age range (from 25 to 64) per 100 population
1.1.3. Youth with upper secondary level education	Percentage youth aged 20-24 лет, having attained at least upper secondary level education (ISCED 3a, 3b, 3c)	Eurostat	Similar to that of EIS 2009
Open, excellent and attractive research systems 1.2.1. International scientific co-publications	Number of scientific co-publications with at least 1foreign scientist per 1,000,000 population	Science Metrix/Scopus (Elsevier)	New indicator. A foreign scientist is the one from outside EU27
1.2.2. Scientific publications among the top 10% most cited publications worldwide	Number of scientific publications among the top 10% most-cited publications worldwide as a percentage of a country's total number of publications	Science Metrix/Scopus (Elsevier)	New indicator
1.2.3. Non-EU doctorate students	Number of PhD students from outside EU27 as a percentage of the total number of all PhD students in a country	Eurostat	New indicator. For countries outside EU27: the number of foreign PhD students
Finance and support 1.3.1. Public R&D expenditure as % of GDP	Public expenses on R&D as a percentage of GDP, including the public sector expenses (GOVERD) and the higher education sector (HERD)	Eurostat	Similar to that of EIS 2009
Firm investment 2.1.1. Business R&D Expenditure as % of GDP	Entrepreneurial expenses on R&D as a percentage of GDP	Eurostat	Similar to that of EIS 2009
Linkages & entrepreneurship 2.2.3. Public-private co-publications	Number of public-and-private co-publications, linked to a country where a private company or organization in located, per 1,000,000 population		Similar to that of EIS 2009. The "private sector" definition excludes private healthcare and health-improving organizations
Intellectual assets 2.3.1. PCT patent applications	Number of patent applications registered on the international phase of The Patent Cooperation Treaty in the European patent Office, per billion GDP (in PP)	OECD/ Eurostat	New indicator. Count of patents is based on the priority date.
2.3.2. PCT patent applications in societal challenges	The same, but applied to socially significant spheres (climate change, renewable energy, healthcare, etc.)	OECD/ Eurostat	New indicator

Table 2: International Standard Classification of Education, UNESCO

Educational levels	Code	Notes
Pre-primary education	0	
Primary education	1	
Lower secondary education. Second stage of basic education	2	
Upper secondary education	3	
Post-secondary non-tertiary education	4	Professional training for certain labour markets
First stage of tertiary education (not leading directly to an advanced research qualification)	5	Mostly university level of education. Academic and professional training
Second stage of tertiary education (leading to an advanced research qualification)	6	Further university education usually leading to obtaining a PhD degree

Table 3: Values of primary relative and specific indicators of the Research and Education Scoreboard for Central and Eastern European countries, IUS 2010

Indicators	BG	CZ	DE	EE	LV	LT	HU	AT	PL	RO	SI	SK	HR	CH	RS	MK	EU 27
	Human resources																
1.1.1	0.50	1.40	2.60	0.80	0.40	0.80	0.70	2.00	0.90	0.90	1.30	1.80	0.80	3.40	0.50	0.30	1.40
1.1.2	27.90	17.50	29.40	35.90	30.10	40.60	23.90	23.50	32.80	16.80	31.60	17.60	20.50	43.50	19.20	14.30	32.30
1.1.3	83.70	91.90	73.70	82.30	80.50	86.90	84.00	86.00	91.30	78.30	89.40	93.30	95.10	80.20	84.70	81.90	78.60
	Open, excellent and attractive research systems																
1.2.1	190	428	587	491	132	199	328	936	186	118	750	333	N/A	N/A	N/A	N/A	266
1.2.2	0.03	0.05	0.12	0.08	0.02	0.04	0.05	0.12	0.04	0.04	0.07	0.03	0.03	0.16	N/A	N/A	0.11
1.2.3	3.97	3.14	N/A	1.82	0.28	0.03	2.95	8.47	2.27	2.01	4.64	0.65	2.55	45.01	8.50	3.36	19.45
	Finance and support																
1.3.1	0.36	0.61	0.90	0.76	0.29	0.64	0.47	0.81	0.41	0.29	0.66	0.28	0.50	0.74	0.38	0.14	0.75
	Firm investments																
2.1.1	0.16	0.92	1.92	0.64	0.17	0.20	0.66	1.94	0.18	0.19	1.20	0.20	0.34	2.20	0.10	0.04	1.25
	Linkages & entrepreneurship																
2.2.3	2.30	24.70	49.50	19.00	2.00	3.00	19.60	56.30	2.50	6.30	51.00	10.30	17.70	198.50	4.20	N/A	36.20
	Intellectual Assets																
2.3.1	0.38	0.99	7.72	1.99	0.69	0.35	1.54	5.05	0.31	0.15	2.56	0.49	0.88	9.13	N/A	0.13	4.00
2.3.2	0.04	0.14	1.01	0.36	0.26	0.02	0.39	0.71	0.06	0.01	0.65	0.08	0.03	2.60	N/A	N/A	0.64
Ij	0.39	0.69	1.46	0.77	0.37	0.48	0.62	1.35	0.45	0.35	1.06	0.51	0.45	2.31	0.45	0.30	0.30

1.1.1.New doctorate graduates; 1.1.2. Population completed tertiary education; 1.1.3. Youth with upper secondary level education; 1.2.1. International scientific co-publications; 1.2.2. Scientific publications among top 10% most cited; 1.2.3. Non-EU doctorate students; 1.3.1. Public R&D expenditure; 2.1.1. Business R&D expenditure; 2.2.3. Public-private co-publications; 2.3.1. PCT patent applications; 2.3.2. PCT patent applications in societal challenges; Ij - Integral indicator

Table 4: Interpretation of abbreviation of Central and Eastern European countries

Abbreviation	Country	Abbreviation	Country
BG	Bulgaria	PL	Poland
CZ	Czech Republic	RO	Romania
DE	Germany	SI	Slovenia
EE	Estonia	SK	Slovakia
LV	Latvia	HR	Croatia
LT	Lithuania	CH	Switzerland
HU	Hungary	RS	Serbia
AT	Austria	MK	Former Yugoslav Republic of Macedonia

Table 5: Classification of CEEC by the level of development of their S&E potential

Value changes of integral indicator	Level of development of S&E potential	CEEC
$0 \le I \le \frac{1}{3}$	Very low	Former Yugoslav Republic of Macedonia
$\frac{1}{3} < I \le \frac{2}{3}$	Low	Romania, Latvia, Bulgaria, Lithuania, Hungary, Poland, Slovakia, Croatia, Serbia
$\frac{2}{3} < I \le 1$	Below average	Czech Republic, Estonia
$1 < I \le \frac{5}{3}$	Above average	Slovenia, Germany, Austria
$\frac{5}{3} < I \le 2$	High	
>2	Very high	Switzerland

its new value: $I_2 = 0.89$, which means that the value of the indicator for the Czech Republic would increase by 29%. Knowing the potential of the Czech Master's and PhD courses, all the above-mentioned forecast indicators can be planned.

An increase in the number of a country's holders of Master's and PhD degrees engaged in research will naturally result in the growth of the scientific output indicators (publications and patents). The growing number of foreign PhD students and their graduation (indicator 1.2.3) will directly affect the growth of the number of international co-publications (indicator 1.2.1). Supposing the value of the latter indicator were brought up to the German level and the values of indicators 1.2.2, 2.3.1 and 2.3.2 were brought up to the average European level, then the value of integral indicator I_2 would increase from 0.89 to 1.13 and the Czech Republic would move to the zone with the "above average" level of development of S&E potential, outrunning Slovenia.

So we have shown how the Research and Education Scoreboard can be used for simulation calculations aimed at reaching the target features of the advanced countries, which is the essence of the benchmarking methodology. It should be noted that such simulation scenario calculations still cannot be found among the analytical techniques of the European Innovation Scoreboard.

Creating Education and Innovation Scoreboard Based on EIS- and GCI-Methodologies for CEEC: We will be using the same procedures of standardization and calculation of the integral indicator used for EIS-methodology (Table 3) to build the Education and Innovation Scoreboard for CEEC with selected groups of indicators GCI [6, 7]. From the GCI Report 2010, we will take two pillar indicators describing the development of education and innovative activity of countries. Their initial values for CEEC are shown in Table 6. In this Table, indicators based on hard data are marked with asterisks. Other indicators are based on survey data and range from 1 to 7.

In the GCI-methodology, hard data are transferred to the above-mentioned range to become compatible with experts' ratings and then are aggregated in a quite complicated way in order to obtain the pooled estimate for all twelve groups of indicators and the integral indicator GCI [4].

As we have noticed above, we will be following the principles of EIS-methodology. We calculated the average values of each indicator for all the CEEC (See "Avg" in Table 6). After this, all the values of the primary indicators were standardized to match the average values and by formula (1) we calculated the values of the integral indicator I_j (Table 6). The Education Scoreboard shows that for half the CEEC the values of the integral indicator are above its average for 16 CEEC, with Switzerland, Austria and Slovenia holding the lead.

The variation of this indicator values across the countries is insignificant (from 0.82 to 1.25), which proves that the educational systems in the CEEC are approximately at the same level, with the Czech Republic and Germany having practically the same value of the indicator, which is slightly above the average for the CEEC. In relation to innovation development, the situation is different. Here the amplitude of fluctuations of the integral indicator value is considerably wider – from 0.72 to 2.22. (Table 6), with only three countries having this indicator values above the average for the CEEC (Germany, Austria and Switzerland). This gap can be explained by a high patent activity in Switzerland and Germany. The constructed scoreboards allow doing simulation calculations aimed at reaching the target features of the more advanced countries. For example, in the Czech Republic, the values of the first six innovation indicators are above the average for the CEEC, while the value of its patent indicator is 5.4 times less than the average for the countries under study. Supposing, the Czech Republic managed to increase this indicator to match the level of Austria (59.9 patents per 1ml of population), then assuming that the values of the indicator in question for other countries remained unchanged, its average level for the CEEC would increase to 26.31. In which case, the standardized value of this indicator for the Czech Republic would equal 59.9/26.31=2.28, while the value of its integral indicator would grow to reach 1.30, which would be very close to the newly recalculated value of this indicator for Austria: (1.29+1.16+1.24+1.22+1.16+1.12+2.28)/7=1.35.

Creating Research and Education Scoreboard Based on EIS- and KA-Methodologies for CEEC: Knowledge Assessment-methodology (KAM) allows a user to select the necessary indicators out of over one hundred indicators and build his own Customized Scoreboard [5]. For the CEEC, we have chosen all educational indicators and indicators showing the total research activity of the countries (Table 7). Here, three indicators whose values are estimated by means of experts' opinions (and ranging from 1 to 7) coincide with the GCI-methodology indicators (Table 6). KA-methodology, after having the values of all the indicators for all the countries ranked, allows recalculating (standardizing) them within the turndown ranging from the value close to 0 to 10 [8]. The integral indicator in KAM (I_j) is calculated as the arithmetic mean of the values of standardized indicators, which is shown in Table 7. Poor comparability of the educational indicators used in GCI- and KA-methodologies is the reason why there is no correlation between the values of the integral indicators for both Education Scoreboards. Moreover, for nine countries at least two indicator values were impossible to obtain, which considerably impaired comparability of integral indicator values even within one Education Scoreboard (Table 7).

Table 6: Values of primary indicators of Education and Innovation Scoreboard for CEEC, GCI 2010

	BG	CZ	DE	EE	LV	LT	HU	AT	PL	RO	SI	SK	HR	CH	RS	MK	Avg.
	5th pillar: Higher education and training																
5.01	88.60	94.90	101.70	99.30	98.00	99.00	97.40	100.00	99.80	91.60	96.80	92.10	93.60	96.10	88.50	83.70	95.07
5.02	51.00	58.60	46.30	63.70	69.20	77.30	65.00	54.70	66.90	65.60	86.70	53.60	47.00	49.40	47.80	40.40	58.95
5.03	3.40	4.50	5.00	4.30	3.80	3.70	3.60	4.90	3.80	3.40	4.20	3.10	3.30	6.00	3.30	3.90	4.01
5.04	4.00	4.90	4.70	4.90	4.20	4.90	4.80	4.70	4.60	4.60	5.20	4.10	4.90	5.90	4.50	4.20	4.69
5.05	3.70	4.40	4.90	4.60	4.20	4.20	4.10	4.90	4.20	3.70	4.60	3.40	3.80	6.10	3.60	4.00	4.28
5.06	4.60	5.70	4.90	6.40	5.40	5.50	5.40	5.80	4.50	4.30	5.70	5.00	4.70	6.20	3.50	4.40	5.13
5.07	3.90	5.40	6.20	4.80	4.10	4.60	4.40	5.90	5.10	3.50	4.70	4.60	4.20	6.50	3.50	3.40	4.68
5.08	2.80	4.40	5.20	4.30	3.90	4.10	3.70	4.90	4.20	3.90	4.10	3.90	3.10	5.50	3.00	3.30	4.02
Ij	0.85	1.07	1.10	1.08	0.99	1.05	0.99	1.12	1.01	0.92	1.11	0.91	0.89	1.25	0.82	0.85	
	12th pillar: Innovation																
12.01	2.80	4.10	5.90	3.60	3.10	3.30	3.40	4.70	3.30	2.90	4.20	2.90	3.00	5.70	2.70	2.70	3.64
12.02	3.50	5.10	5.90	4.70	3.80	4.20	5.20	5.10	4.10	3.30	4.70	3.30	4.00	6.20	3.90	3.50	4.41
12.03	2.70	4.00	5.70	3.30	2.70	3.10	3.00	4.30	3.00	2.70	3.70	3.00	3.10	5.90	2.60	2.60	3.46
12.04	3.00	4.50	5.20	4.20	3.50	4.20	4.30	4.90	3.60	3.10	4.20	3.30	3.40	5.70	3.50	3.50	4.01
12.05	3.40	4.20	4.20	4.10	3.10	3.20	3.20	4.10	3.70	3.20	3.70	2.70	2.90	4.40	3.20	3.10	3.53
12.06	4.00	4.40	4.80	4.20	3.60	4.40	4.40	4.70	4.20	4.30	4.00	4.00	3.80	5.30	3.70	3.60	4.21
12.07	4.80	4.20	109.50	2.30	2.30	0.90	4.60	59.90	0.90	0.40	11.00	1.90	3.60	158.90	0.10	0.00	22.83
Ij	0.75	1.00	1.86	0.90	0.74	0.83	0.89	1.40	0.81	0.72	0.97	0.72	0.77	2.22	0.72	0.70	

5.01 Secondary education enrollment rate*; 5.02 Tertiary education enrollment rate*; 5.03 Quality of the educational system; 5.04 Quality of math and science education; 5.05 Quality of management schools; 5.06 Internet access in schools; 5.07 Local availability of specialized research and training services; 5.08 Extent of staff training; Ij - Integral indicator; 12.01 Capacity for innovation; 12.02 Quality of scientific research institutions; 12.03 Company spending on R&D; 12.04 University-industry collaboration in R&D; 12.05 Government procurement of advanced technology products; 12.06 Availability of scientists and engineers; 12.07 Utility patents*

* - hard data

Table 7: Values of primary indictors of Research and Education Scoreboard for CEEC, KAM 2009

	BG	CZ	DE	EE	LV	LT	HU	AT	PL	RO	SI	SK	HR	CH	RS	MK	Avg.
	Research Scoreboard																
1.1.	25.96	29.17	n/a	22.36	15.22	24.11	17.69	24.19	22.24	22.91	21.08	25.44	23.73	24.10	n/a	n/a	22.94
1.2.	4.98	9.47	n/a	10.05	5.18	6.12	5.25	12.38	9.67	4.68	5.44	9.05	7.42	10.72	n/a	n/a	7.72
1.3.	1343.64	2578.02	3385.73	2621.69	1757.90	2357.88	1744.50	3656.83	1561.94	952.36	2923.78	2185.53	1148.37	3436.12	n/a	547.18	2146.76
1.4.	99.03	309.95	535.73	326.09	58.24	118.93	259.59	554.81	179.58	41.01	517.59	171.11	214.55	1178.17	114.10	21.04	234.76
1.5.	0.83	3.55	130.96	3.27	1.13	1.53	5.47	70.20	0.70	0.41	10.28	0.89	2.88	177.82	0.19	0.10	25.64
1.6	65.01	52.50	46.66	52.43	73.18	55.29	55.80	57.29	47.48	67.80	49.71	59.07	39.01	59.32	n/a	68.18	56.53
1.7.	1.11	1.49	2.57	1.66	0.95	1.12	1.69	2.34	1.28	0.87	1.29	1.05	1.01	3.20	n/a	1.20	1.52
Ij	5.37	6.66	7.62	6.39	4.57	5.59	5.45	7.76	5.42	4.37	5.64	5.88	4.87	7.99	6.15	4.72	
	Education Scoreboard																
2.1.	98.28	100.00	100.00	99.79	99.78	99.68	98.89	100.00	99.31	97.60	99.68	99.60	98.72	100.00	96.40	96.10	98.99
2.2.	9.47	9.48	10.20	n/a	n/a	n/a	9.10	8.35	9.84	9.51	7.11	9.27	6.28	10.48	n/a	n/a	9.01
2.3.	106.07	96.17	100.69	99.86	98.55	98.82	95.50	101.89	99.55	85.87	95.46	94.30	91.12	92.69	87.92	83.99	95.53
2.4.	49.52	54.82	50.10	65.04	71.31	75.56	69.10	51.07	66.95	58.26	85.53	50.85	45.78	47.00	n/a	35.51	58.43
2.5.	73.00	77.00	80.00	73.00	71.00	71.00	73.00	80.00	75.00	73.00	78.00	74.00	76.00	82.00	73.00	74.00	75.19
2.6.	3.70	5.40	4.80	6.40	4.70	4.50	5.00	6.10	4.10	4.00	5.60	4.60	4.10	6.00	3.20	3.00	4.70
2.7.	5.00	4.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	3.00	6.00	4.00	5.00	6.00	4.00	n/a	4.80
2.8.	n/a	486.00	525.00	n/a	537.00	530.00	510.00	505.00	n/a	n/a	502.00	496.00	n/a	n/a	n/a	n/a	511.38
2.9.	n/a	515.00	528.00	n/a	542.00	514.00	536.00	526.00	n/a	n/a	518.00	526.00	n/a	n/a	n/a	n/a	525.63
2.10.	464.00	504.00	n/a	n/a	n/a	506.00	517.00	n/a	n/a	461.00	501.00	n/a	n/a	n/a	486.00	n/a	491.29
2.11.	470.00	539.00	n/a	n/a	n/a	519.00	539.00	n/a	n/a	462.00	538.00	n/a	n/a	n/a	470.00	n/a	505.29
2.12.	4.40	5.60	4.60	5.30	4.30	5.10	4.80	5.00	4.70	5.10	5.00	4.80	5.00	5.70	5.00	4.40	4.93
2.13.	3.70	4.70	5.10	4.80	4.40	4.30	3.90	5.30	4.50	3.80	4.60	4.00	3.90	6.00	3.70	3.70	4.40
2.14.	413.00	510.00	504.00	515.00	486.00	486.00	491.00	505.00	495.00	415.00	504.00	492.00	467.00	530.00	435.00	n/a	483.20
2.15.	434.00	513.00	516.00	531.00	490.00	488.00	504.00	511.00	498.00	418.00	519.00	488.00	493.00	512.00	436.00	n/a	490.07
Ij	5.84	7.41	7.93	8.24	6.99	6.93	7.24	7.83	7.27	5.30	7.56	6.30	6.20	8.79	5.07	5.14	

Research Scoreboard: 1. 1.Science and Engineering Enrolment Ratio (%), 2007; 1.2. Science Enrollment Ratio (%), 2007;1.3. Researchers in R&D / Mil. People, 2006; 1.4. S&E Journal Articles / Mil. People, 2005; 1.5. Patents Granted by USPTO / Mil. People, avg 2003-2007; 1.6. S&E international co-publications (%), 2005; 1.7. avg number of citations per S&E article, 2005; Ij - Integral indicator

Education Scoreboard: 2.1.Adult Literacy Rate (% age 15 and above), 2007; 2.2.Average Years of Schooling, 2000; 2.3.Gross Secondary Enrollment rate, 2007; 2.4.Gross Tertiary Enrollment rate, 2007; 2.5.Life Expectancy at Birth, 2007; 2.6.Internet Access in Schools (1-7), 2008; 2.7.Public Spending on Education as % of GDP, 2007; 2.8.4th Grade Achievement in Math(TIMSS), 2007; 2.9.4th Grade Achievement in Science(TIMSS), 2007; 2.10. 8th Grade Achievement in Math(TIMSS), 2007; 2.11.8th Grade Achievement in Science(TIMSS), 2007; 2.12.Quality of Science and Math Education (1-7), 2008; 2.13.Quality of Management Schools (1-7), 2008; 2.14.15-year-olds' math literacy (PISA), 2006; 2.15. 15-year-olds' science literacy (PISA), 2006; Ij - Integral indicator

Table 8: Values of standardized and integral indicators of Research and Education Scoreboard for CEEC (indicators obtained from KAM, calculations done according to EIS-methodology)*

	BG	CZ	DE	EE	LV	LT	HU	AT	PL	RO	SI	SK	HR	CH	RS	MK
	Research Scoreboard															
1.1.	1.13	1.27	n/a	0.97	0.66	1.05	0.77	1.05	0.97	1.00	0.92	1.11	1.03	1.05	n/a	n/a
1.2.	0.64	1.23	n/a	1.30	0.67	0.79	0.68	1.60	1.25	0.61	0.70	1.17	0.96	1.39	n/a	n/a
1.3.	0.63	1.20	1.58	1.22	0.82	1.10	0.81	1.70	0.73	0.44	1.36	1.02	0.53	1.60	n/a	0.25
1.4.	0.42	1.32	2.28	1.39	0.25	0.51	1.11	2.36	0.76	0.17	2.20	0.73	0.91	n/a	0.49	0.09
1.5.	0.03	0.14	5.11	0.13	0.04	0.06	0.21	2.74	0.03	0.02	0.40	0.03	0.11	6.94	0.01	0.00
1.6.	1.15	0.93	0.83	0.93	1.29	0.98	0.99	n/a	0.84	1.20	0.88	1.04	0.69	1.05	n/a	1.21
1.7.	0.73	0.98	1.69	1.09	0.62	0.74	1.11	1.54	0.84	0.57	0.85	0.69	0.66	2.10	n/a	0.79
Ij	0.68	1.01	2.30	1.00	0.62	0.75	0.81	1.83	0.77	0.57	1.05	0.83	0.70	2.35	0.25	0.47
	Education Scoreboard															
2.1.	0.99	1.01	1.01	1.01	1.01	1.01	1.00	1.01	1.00	0.99	1.01	1.01	1.00	1.01	0.97	0.97
2.2.	1.05	1.05	1.13	n/a	n/a	n/a	1.01	0.93	1.09	1.06	0.79	1.03	0.70	1.16	n/a	n/a
2.3.	1.11	1.01	1.05	1.05	1.03	1.03	1.00	1.07	1.04	0.90	1.00	0.99	0.95	0.97	0.92	0.88
2.4.	0.85	0.94	0.86	1.11	1.22	1.29	1.18	0.87	1.15	1.00	1.46	0.87	0.78	0.80	n/a	0.61
2.5.	0.97	1.02	1.06	0.97	0.94	0.94	0.97	1.06	1.00	0.97	1.04	0.98	1.01	1.09	0.97	0.98
2.6.	0.79	1.15	1.02	1.36	1.00	0.96	1.06	1.30	0.87	0.85	1.19	0.98	0.87	1.28	0.68	0.64
2.7.	1.04	0.83	1.04	1.04	1.04	1.04	1.04	1.04	1.04	0.63	1.25	0.83	1.04	1.25	0.83	n/a
2.8.	n/a	0.95	1.03	n/a	1.05	1.04	1.00	0.99	n/a	n/a	0.98	0.97	n/a	n/a	n/a	n/a
2.9.	n/a	0.98	1.00	n/a	1.03	0.98	1.02	1.00	n/a	n/a	0.99	1.00	n/a	n/a	n/a	n/a
2.10.	0.94	1.03	n/a	n/a	n/a	1.03	1.05	n/a	n/a	0.94	1.02	n/a	n/a	n/a	0.99	n/a
2.11.	0.93	1.07	n/a	n/a	n/a	1.03	1.07	n/a	n/a	0.91	1.06	n/a	n/a	n/a	0.93	n/a
2.12.	0.89	1.14	0.93	1.08	0.87	1.04	0.97	1.02	0.95	1.04	1.02	0.97	1.02	1.16	1.02	0.89
2.13.	0.84	1.07	1.16	1.09	1.00	0.98	0.89	1.20	1.02	0.86	1.05	0.91	0.89	1.36	0.84	0.84
2.14.	0.85	1.06	1.04	1.07	1.01	1.01	1.02	1.05	1.02	0.86	1.04	1.02	0.97	1.10	0.90	n/a
2.15.	0.89	1.05	1.05	1.08	1.00	1.00	1.03	1.04	1.02	0.85	1.06	1.00	1.01	1.04	0.89	n/a
Ij	0.93	1.02	1.03	1.09	1.02	1.03	1.02	1.04	1.02	0.91	1.06	0.97	0.93	1.11	0.90	0.83

*the legend to this table is similar to that to Table 7

Table 9: Aggregated indicators across a range of indicators obtained by using EIS-, GCI- and KA –methodologies on the example of CEEC

Country	Ij(EIS)	Ij(GCI,EIS)	Ij(KAM)	Ij(KAM,EIS)	Ij(H)
CH	2.31	1.735	8.39	1.73	1
DE	1.46	1.48	7.775	1.665	0.812
AT	1.35	1.26	7.795	1.435	0.715
SI	1.06	1.04	6.6	1.055	0.503
EE	0.77	0.99	7.315	1.045	0.474
CZ	0.69	1.035	7.035	1.015	0.457
HU	0.62	0.94	6.345	0.915	0.391
LT	0.48	0.94	6.26	0.89	0.365
PL	0.45	0.91	6.345	0.895	0.362
SK	0.51	0.815	6.09	0.9	0.353
LV	0.37	0.865	5.78	0.82	0.311
HR	0.45	0.83	5.535	0.815	0.308
BG	0.39	0.8	5.605	0.805	0.296
RO	0.35	0.82	4.835	0.74	0.253
MK	0.3	0.775	4.93	0.65	0.211
RS	0.45	0.77	5.61	0.575	0.207

Table 10: Matrix of cross-correlation for the first four indicators from Table 9

	Ij(EIS)	Ij(GCI,EIS)	Ij(KAM)	Ij(KAM,EIS)
Ij(EIS)	1			
Ij(GCI,EIS)	0.973	1		
Ij(KAM)	0.872	0.886	1	
Ij(KAM,EIS)	0.938	0.970	0.914	1

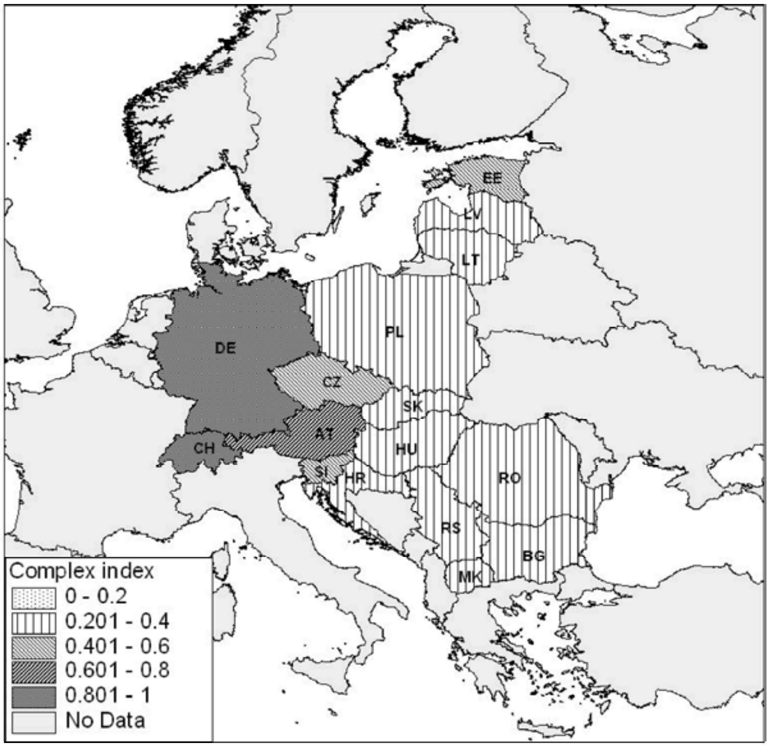

Fig. 1: Mapping of CEEC based on the complex index (method of equal intervals)

A better situation is observed for the Research Scoreboard (a wider data scope), but still there is no comparability with the innovation indicators for the Innovation Scoreboard (Table 6) and no correlation between the values of the integral indicators of both scoreboards. Nevertheless, according to these scoreboards the leaders are Switzerland, Austria and Germany.

Taking the indicator values from KAM 2009 (Table 7) and applying EIS-methodology to them in order to calculate the integral indicator values, we will obtain the results shown in Table 8 (analogous to Table 6, with the indicators from GCI-methodology and calculations according to EIS-methodology). On the whole, the integral indicator values for the CEEC, calculated in two different ways using the initial KAM 2009 data, correlate to each other (Tables 7 and 8). Though, there are a number of discrepancies: for example, in Table 7, $I_{SI} > I_{SK}$, $I_{LT} < I_{HU}$, but in Table 8 the inequalities are opposite. It is caused by different standardizing procedures used in EIS- and KA-methodologies.

Aggregated Approach to All Types of Scoreboards: After aggregating the integral indicators from the Education and Innovation Scoreboard (Table 6) and from the Research and Education Scoreboard (Tables 7, 8) as the arithmetic mean value, we can present them along with the integral indicator EIS (IUS) in Table 9. On the basis of these three aggregated indicators and one integral indicator of EIS-methodology, using the Polish taxonomy method (Helwig's method [9, 10], we have calculated the development index Ij(H) (Table 9), which we'll call "the complex index" when mapping the CEEC.

In addition to Table 9, there has been constructed a matrix of cross-correlation for the first four indicators from this Table (Table 10). From this matrix, we can see that the best correlation could be observed among the indictors calculated according to the EIS-methodology.

Mapping of CEEC Based on the Complex Index: To illustrate the geographic peculiarities of the educational and innovative potential of the CEEC we have created the maps on which the countries under study are marked differently according to the complex index of the educational and innovative potential (Ij(H) in Table 9). The maps have been constructed in the Geographic Information System (GIS) ArcView. The classification of the countries by their educational and innovative potential has been made using two methods whose algorithms are incorporated in GIS ArcView: the method of equal intervals (Fig. 1) and the method of natural boundaries (Fig. 2). In both cases there were singled out 5 classes of the educational and innovative potential of countries.

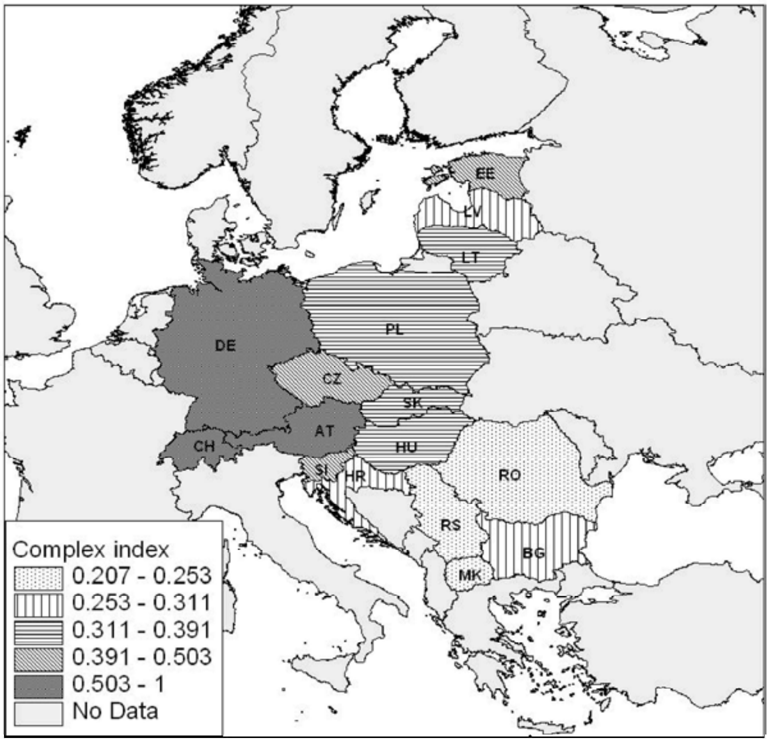

Fig. 2: Mapping of CEEC based on the complex index (method of natural boundaries)

Applying both methods, we can see a tendency of growing educational and innovative potential of countries when moving westwards.

Applying the method of equal intervals only two countries were put down into the first class with the highest complex index: Switzerland and Germany. The class with the second highest complex index includes only one country – Austria. Almost all post-socialist countries were put down in the last but one class except for Slovenia, the Czech Republic and Estonia - which were placed in the third class. The remaining ten countries got into the fourth class. No countries were placed in the fifth class (with the lowest complex index) (Fig. 1).

When applying the method of natural boundaries. Austria along with Switzerland and Germany was put down into the class with the highest complex index. However, using this method allowed us to thoroughly determine the differences in the educational and innovative potential of the post-socialist countries. This time, the second class includes three countries: Slovenia, the Czech Republic and Estonia – which, when applying the method of equal intervals, were referred to the third class. The third class now includes four countries: Poland, Slovakia, Hungary and Lithuania. Three countries – Croatia, Bulgaria and Latvia – got in the fourth class. Three countries with the unstable political and socio-economic situation –Romania, Former Yugoslav Republic of Macedonia and Serbia - were placed in the fifth class with the lowest complex index of the educational and innovative potential (Fig. 2).

The first method of mapping we applied is obviously more plausible.

CONCLUSION

In the paper, we have used three methodologies of territorial benchmarking to build a series of Education, Research and Innovation Scoreboard for CEEC. Through these scoreboards, we have suggested using simulation calculations which so far have never been used among the analytical techniques of these methodologies.

When using EIS-methodology, there has been constructed a classification of CEEC according to the level of development of their S&E potential. This classification demonstrated a considerable territorial asymmetry in distributing the countries under study in comparison with the average European development level: four countries with their S&E potential development levels ranging from “above average” to “very high” (Slovenia, Germany, Austria and Switzerland) and twelve countries with their S&E potential development levels ranging from “very low” to “below average” (Former Yugoslav Republic of Macedonia, Romania, Latvia, Bulgaria, Lithuania, Hungary, Poland, Slovakia, Croatia, Serbia, the Czech Republic and Estonia).

Applying both EIS- and GCI-methodologies has demonstrated a slight variation of the integral indicator of the Education Scoreboard, which suggests that the educational systems of CEEC are approximately on the same development level. The picture is different for the innovative development of the countries under study. It is mostly due to a large gap between Switzerland and Germany and their competitors.

A good correlation has been found between the integral indicators in the education and Research Scoreboards, calculated within KAM and the combination of EIS- and KA-methodologies. Some discrepancies appearing here are due to different standardization procedures of individual indicators in EIS- and KA-methodologies.

Aggregating integral indicators across all the constructed scoreboards into one complex index by means of the Polish taxonomy method has allowed doing the mapping of CEEC. The maps have been constructed in the Geographic Information System (GIS) ArcView. The classification of the countries by their educational and innovative potential has been made using two methods, whose algorithms are incorporated in GIS ArcView: the method of equal intervals and the method of natural boundaries. In both cases, there were singled out 5 classes of the educational and innovative potential of countries. Applying both methods, we can see a tendency of growing educational and innovative potential of countries when moving westwards.

REFERENCES

1. Camp, R.C., 1989. Benchmarking: the search for industry best practices that lead to superior performance. ASQC Quality Press, pp: 299.
2. Bogan, C.E. and M.J. English, 1994. Benchmarking for best practices: winning through innovative adaptation. 1. New York: McGraw-Hill, pp: 312.
3. Arundell, A. and H. Hollanders, 2003. European Innovation Scoreboard. Technical Paper. 6. Methodology Report. European Trend Chart on Innovation. European Commission Enterprise Directorate-General, pp: 29.
4. Sala-I-Martin, X., J. Blanke, H.M. Drzeniek, T.H. Geiger, I. Mia and F. Paua, 2008. The Global Competitiveness Index: Prioritizing the Economic Policy Agenda. The Global Competiveness Report 2008-2009. World Economic Forum, Geneva, Switzerland, pp: 3-42.
5. Chen, D.H.C. and C.J. Dahlman, 2005. The Knowledge Economy, the KAM Methodology and World Bank Operations. The World Bank Washington DC 20433, pp: 33. Date Views 01.01.2013 www.siteresources.worldbank.org/KFDLP/Resources/KAM_Paper_WP.pdf.
6. Moskovkin, V.M., T. Delux and E.A. Bader, 2009. Development of the Methodology of Comparative Analysis of Global Competitiveness of Countries: on the Example of ASEAN and MEDA Countries. International Economy, 7: 33-43.
7. Moskovkin, V.M., E.A. Bader and G. Salakh, 2009. Comparative Analysis of National Innovative Systems by Means of Global Competitiveness Index (on the example of the MEDA countries). Economics and Management, 9: 32-38.
8. Moskovkin, V.M., T. Delux and E.A. Bader, 2011. Development of the World Bank Methodology of Knowledge Assessment and Its Appendices (on the example of the ASEAN and MEDA countries). International Economy, 4: 59-76.
9. Helwig, Z., 1968. Zastosowanie metody taksonomicznej do typologicznego podzialu Krajow ze wzgledu ha poziom ich rozwoju i strukture wykwalifikowakych Kadr. Przeglad Staistyczhy, 4. [in Polish].
10. Helwig, Z., 1972. The Selection of a Set of “Core” Indicators of Socio-economic Development. UNESCO.