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Letters to the Editor

LETTER TO THE EDITOR

A comparative analysis of scientific outputs of countries formed from former Yugoslav republics and some other countries for the period 2008–2012

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Abstract: Scientific outputs of six countries (republics of the former Yugoslavia – the Socialist Federal Republic of Yugoslavia): Serbia, Croatia, Slovenia, Bosnia and Herzegovina, Former Yugoslav Republic of Macedonia and Montenegro were discussed in this paper. For the purpose of comparison, the data for seven neighbouring countries of the former Yugoslavia (Albania, Greece, Bulgaria, Romania, Hungary, Austria and Italy) were given as well. Also, the data for the Group of Eight (G8) countries (the United States, Canada, the United Kingdom, France, Italy, Germany, Japan and the Russian Federation) and some European countries similar in population to ex-Yugoslav republics were included. To gain a more complete picture on the outputs in scientific production (*e.g.*, publications and patents), data on several developed European countries, as well as the countries from other continents were given. The analysis, which included 33 countries, was made based on different bibliometric indicators for the period of five years (2008–2012). The data were collected from international databases.

Keywords: bibliometric analysis; scientific productivity; ex-Yugoslav republics.

INTRODUCTION

Bibliometric analysis is a useful method for the characterization of scientific research. It provides the best available measures of scientific "output" by the world's countries. There are plenty of articles devoted to the scientific production of individual countries in the literature. Only a few of them are mentioned here.[1-3] However, a small amount of data on scientific outputs of the countries arising from the former Yugoslav republics can be found.

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Kutlača *et al.*[4] presented a comprehensive comparative analysis of 13 South East European countries (including all republics of the former Yugoslavia) according to their scientific outputs in the period of 2005–2010. An analysis of the scientific production in the Republic of Serbia, for the last several years, was made by Ivanovic and coworkers.[5,6] Kastrin *et al.*[7] made a comprehensive analysis of the performance of the Slovenian research community between the years 1970 and 2015 with the focus on productivity, collaboration, internationality and interdisciplinarity. They demonstrated a fast increase in scientific productivity after the year 1992, soon after Slovenia won the independence from Yugoslavia, its climax reached in 2011 and then a steady decline. The average number of publications per author increased a lot in the period 1990–2010, stabilizing in the years 2011–2015. They concluded that political and financial instability has always had an impact (mostly negative) on the scientific productivity. Igić[8] also investigated the influence of the civil war during disintegration of the former Yugoslavia on scientific outputs, as measured by changes in numbers of articles published in peer-reviewed journals. The annual numbers of articles from each republic were determined from 1988 to 2000. Lewison and Igic[9] investigated scientific outputs from Serbia, Croatia and Slovenia, and the patterns of co-authorship between them and five western countries and with each other. They studied the influence of the war on scientific outputs, as measured by the changes in the number of papers indexed in the Science Citation Index from various parts of the former Yugoslavia. The number of papers from each of these states was determined from 1985 to 1996. Recently, Ivanović *et al.*[10] have shown that the Yugoslav wars affected the republics' productivities and scientific cooperation in different ways. The most affected republics by wars and social crisis were Serbia and Bosnia & Herzegovina, while the least affected ones were Slovenia and FYR Macedonia. Also, there are a few studies[11–15] on the scientific productivity of researchers from the Republic of Croatia, a constituent republic of the former Yugoslavia up to 1991.

This letter offers a comparative analysis of the scientific research outputs of Serbia, Croatia, Slovenia, Bosnia and Herzegovina, Macedonia and Montenegro for the period 2008-2012, *i.e.*, after these states declared independence. The last of them, Montenegro, reached its statehood after the referendum held in 2006. Integration of Slovenia and Croatia into the European Union resulted in significant increase in their research and development, due to granted EU projects/programs.

METHODS

The study is based on data obtained from online available databases of: SCImago, SJR-SCImago Journal & Country Rank, ARWU – The Academic Ranking of World Universities, The World Bank, and OECD – the Organization for Economic Co-operation and Development, for the period from 2008 to 2012.

RESULTS AND DISCUSSIONS

The data on population, GDP (gross domestic product) per capita, as well as the research and development expenditure for 33 selected countries for the period 2008–2012 are given in Table I. Of all given countries, Montenegro has the smallest population (0.620 million) and China the largest (1,337,689 million). GDP per capita, as a measure of the level of economic development of a country, ranges from US $ 1,326 (India) to 91,701 (Norway).

TABLE I. Population, gross domestic product per capita (current US dollars) and R&D expenditure from 2008 to 2012, according to: http://data.worldbank.org/indicator/ /SP.POP.TOTL and http://data.worldbank.org/indicator/NY.GDP.PCAP.CD

No.	Country	Population 2008–2012 (in million)	GDP per capita 2008–2012 (in US $)	R&D expenditure (% of GDP)
1	Serbia	7.289	5,645	0.35
2	Croatia	4.366	14,147	0.82
3	Bosnia & Herzegovina	3.847	4,559	0.33
4	Slovenia	2.044	24,097	1.87
5	Macedonia, FYR	2.102	4,614	0.44
6	Montenegro	0.620	6,944	0.41
7	Albania	3.155	3,995	0.15
8	Bulgaria	7.479	6,762	0.53
9	Romania	21.429	8,264	0.51
10	Hungary	9.990	13,646	1.17
11	Greece	11.282	26,483	0.68
12	Italy	60.430	35,309	1.24
13	Austria	8.396	47,452	2.72
14	United Kingdom	62.291	38,437	1.80
15	Sweden	9.372	51,609	3.57
16	Denmark	5.545	58,281	2.99
17	Finland	5.363	46,982	3.84
18	Netherlands	16.610	48,777	1.81
19.	Norway	4.892	91,701	1.68
20.	Spain	45.985	31,565	1.38
21	Switzerland	7.825	73,459	2.99
22	France	65.035	41,192	2.21
23	Germany	81.895	42,021	2.78
24	Portugal	10.595	21,961	1.58
25	Poland	38.308	12,715	0.67
26	Russian Federation	142.548	11,669	1.15
27	USA	309.139	47,352	2.87
28	Canada	34.107	46,949	1.86
29	Brazil	195.211	10,378	1.15
30	Korea Rep.	49.465	20,301	3.56
31	Japan	127.618	42,683	3.42
32	India	1,203.710	1,326	0.84
33	China	1,337.689	4,648	1.58

It is evident that the former Yugoslav republics, except Croatia and Slovenia, compared with other countries have low gross domestic product per capita. Such a low GDP per capita can also be seen for the three neighbouring countries of ex-Yugoslavia (Albania, Bulgaria and Romania). Therefore, a conclusion, based on the data given, is that the Balkan countries are the least developed ones.

In the same table (the fifth column), data on the gross domestic expenditure on research and development, as a percentage of GDP, are given (R&D expenditure). According to the presented figures for all countries, the lowest research and development expenditure was recorded in Albania (0.15 %) and the highest in Finland (3.84 %). As for the countries formed from the former Yugoslavia, the highest R&D expenditure is in Slovenia and Croatia, while in other countries (former Yugoslav republics), it is less than 0.5 %. These data correlate well with the scientific outputs in these countries. The inadequate budget for R&D with the already lowest gross national income per capita inevitably reflects in the modest productivity of researchers in these countries. Also, the inadequate budget (less than 1 % of GDP) can be seen in most neighbouring countries of the former Yugoslavia (Albania, Bulgaria, Romania and Greece). Poland and India form a group of countries with GDP less than 1 %. Slovenia, Hungary, Italy, the United Kingdom, the Netherlands, Norway, Spain, Portugal, the Russian Federation, Canada, Brazil, and China belong to the group of countries with GDP between 1 and 2 %. The countries spending between 2 and 3 % of GDP on R&D are Austria, Finland, Switzerland, France, Germany and the USA, while Sweden, Finland, the Republic of Korea and Japan spend more than 3 % of GDP.

Table II compares the total number of publications and their citations for all studied countries over the study period. Citation, however, is not a direct measure of the quality and the academic significance of an article but reflects its visibility and impact on the scientific community[16,17]. The highest citation in the case of Serbia[5] is connected with the articles that were products of international cooperation with corresponding authors with no address in Serbia. The articles co-authored by at least one researcher from Serbia in 2006–2013, cited more than 300 times (in total, eight articles), are characterized by the number of co-authors usually more than 10, but the first and the corresponding author are not from Serbia.[5]

For a better comparison, the ratio of citations to the number of publications (calculated by dividing data from column 4 by those from column 3) is given in column 5. Of all 6 countries emerged from the former Yugoslavia, the highest citations/publication ratio has Slovenia. Also, the ratios of these countries are much lower than those of the others. Such low ratios are noticed for Albania, Romania, the Russian Federation, India and China. In the same table (next to the last column), the data on self-citation are gathered as well, given in percent. Self-citations range from 10.4 % (Albania) to 54.38 % (China).

TABLE II. Number of publications, citations, citations per publications, self-citations and H-index, from 2008 to 2012, according to: SCImago (2007), SJR-SCImago Journal & Country Rank. Retrieved November 12–18, 2014, from http://www.scimagojr.com

No.	Country	Publications	Citations	Cit./publ.	Self-citations[a] %	H-index[a] (order)
1	Serbia	27,194[b]	108,118	3.49	27.08	86 (29)
2	Croatia	28,497	112,329	5.79	22.24	161 (26)
3	Bosnia & Herzegovina	3,337	7,849	3.48	14.71	49 (31)
4	Slovenia	24,569	140,265	8.73	19.69	172 (25)
5	Macedonia, FYR	2,961	9,163	5.59	12.18	67 (30)
6	Montenegro	981	3,320	2.62	22.16	23 (33)
7	Albania	1,066	2,284	4.21	10.4	40 (32)
8	Bulgaria	18,307	83,877	7.65	16.73	154 (27)
9	Romania	57,802	170,836	4.59	25.25	153 (28)
10	Hungary	44,963	284,434	11.4	16.34	277 (23)
11	Greece	85,635	579,729	11.1	17.02	295 (22)
12	Italy	411,261	3,286,702	14.1	23.31	654 (7)
13	Austria	94,481	798,529	15.2	13.79	416 (14)
14	United Kingdom	769,857	6,794,401	17.5	23.58	934 (2)
15	Sweden	145,830	1,455,129	19.4	15.7	567 (10)
16	Denmark	93,463	966,366	19.8	14.4	476 (12)
17	Finland	76,909	682,709	17.3	15.87	407 (15)
18	Netherlands	234,413	2,501,187	19.7	16.55	636 (8)
19	Norway	75,329	625,790	15.3	16.16	362 (17)
20	Spain	354,267	2,573,254	12.4	24.84	531 (11)
21	Switzerland	170,147	1,925,206	20.8	13.65	629 (9)
22	France	512,152	3,154,317	14.9	22.72	742 (4)
23	Germany	706,143	5,886,941	15.4	26.00	815 (3)
24	Portugal	77,754	513,491	10.3	19.9	269 (24)
25	Poland	151,069	680,400	7.58	26.13	336 (21)
26	Russian Federation	198,281	632,834	5.73	29.72	355 (18)
27	USA	2,751,023	24,399,854	19.5	47.71	1,518 (1)
28	Canada	423,586	3,663,476	17.0	19.02	725 (5)
29	Brazil	247,654	1,115,495	7.86	33.98	342 (19)
30	Korea Rep.	299,069	1,688,568	8.76	22.2	375 (16)
31	Japan	615,605	3,630,154	12.2	28.91	694 (6)
32	India	400,406	1,584,765	6.52	34.56	341 (20)
33	China	1,674,843	6,127,888	4.71	54.38	436 (13)

[a]According to: Self-citations and H-index for the period 1996–2013; b27,879 according to daily newspaper "Politika" from 7 May, 2017

All high-quality papers have been published in international journals and in English. A lot of countries have their own journals in their native languages. Therefore, the articles of most researchers from these countries have been published in their own language; examples are China and the Russian Federation. According to the Russian Science Citation Index (RSCI), a bibliographic database of scientific publications in Russian established in 2005, the total number of

publications in Russia, between 2008 and 2012, is 6,829,000. RSCI accumulates more than 20 million publications of Russian authors, as well as the information about citing these publications from more than 5,000 Russian journals (only 154 of them included in Web of Science in 2014)[18]. This explains high self-citations in these countries. Hence, preferential US citing of US papers is not a surprising thing.

The last column in Table II contains Hirsch index (H-index) data for each studied country. H-indices go from 23 (Montenegro) to 1,518 (the US). Among the countries arose from the former Yugoslavia, the highest H-index have Slovenia and Croatia. The ranking of the studied countries according to the H-index is given in parentheses. As evident, at the very top is the US (H = 1,518) and on the bottom Montenegro (H = 23). All G8 countries have high H-index and are ranked from 1 to 7. The exception is Russia with H-index of 18.

It is useful to compare the scientific output (number of publications) with the number of inhabitants and the number of researches in particular country. Table III (column 3) provides the number of researchers per million inhabitants for all studied countries, for the period 2008–2012. As evident, the lowest number of researchers has India (137) and the highest has Finland (7,685). In the case of the former Yugoslav republics, the lowest number of researchers (217) has Bosnia and Herzegovina and the highest has Slovenia (3,653). All G8 countries, as well as the EU ones have high number of researchers/millions of inhabitants. Albania, with 147 researchers/millions of inhabitants, is according to this criterion, closely behind India.

In the same table, column 4, data on the number of publications per 1000 inhabitants are given, while the column 5 in the same table contains the data on the number of publications per researcher. The data given in these two columns enable comparison of all countries according to the uniform criteria. Of all countries studied, the number of publications per 1000 inhabitants is the lowest for India (0.33) and Albania (0.34). The highest number of publications per 1000 inhabitants can be observed for Switzerland (21.7). The G8 countries, apart from Russia, have high number of publications per 1000 inhabitants. This indicator ranges from 6.80 (Italy) to 21.7 (Switzerland). The number of publications per 1000 inhabitants for the countries formed from the former Yugoslavia goes from 0.87 (Bosnia and Herzegovina) to 12.0 (Slovenia). Only for Slovenia and Croatia this number is higher than 6, while in the case of other countries it is lower than 5. Albania, Bulgaria, Romania and Hungary, the neighbouring countries of the former Yugoslavia, have low number of publications per 1000 inhabitants (< 5). This ratio for China is also low (1.25) in contrast to all developed countries that have high number of publications per 1000 inhabitants.

As for the number of publications per researcher (Table III, column 5), the lowest number according to this criterion is evident for Russia (0.45), with Switz-

erland (6.55) in the lead. The number of publications per researcher for the countries emerged from the former Yugoslavia ranges from 2.08 (Montenegro) to 4.16 (Croatia). Contrary to the previous criteria, the data based on this one, for all studied countries, do not vary greatly. One should have in mind that we took the account of the total number of publications making no distinction in quality between them, *i.e.*, impact factors of journals in which these papers were published.

TABLE III. Number of researchers per million inhabitants, publications/1000 inhabitants, publications/researcher, R&D expenditure/inhabitant, and R&D expenditure /researcher, for the period 2008 to 2012 according to: http://data.woldbank.org/indicator/SP.POP.SCIE.RD.P6

No.	Country	No. of researchers per million inhabitants	Publications per 1000 inhabitants	Publications per researcher	R&D expend./inhab. US $	R&D expend./researcher US $\times10^{-4}$
1	Serbia	1,037	3.73	3.60	20	1.90
2	Croatia	1,567	6.53	4.16	116	7.40
3	Bosnia & Herzegovina	217	0.87	4.00	15	6.93
4	Slovenia	3,653	12.0	3.29	451	12.34
5	Macedonia, FYR	613	1.41	2.30	20	3.31
6	Montenegro	760	1.58	2.08	28	3.75
7	Albania	147	0.34	2.30	6	4.08
8	Bulgaria	1,515	2.45	1.62	36	2.36
9	Romania	904	2.70	2.98	42	4.66
10	Hungary	2,394	4.50	1.88	160	6.67
11	Greece	2,232	7.59	3.40	180	8.07
12	Italy	1,719	6.80	3.96	438	25.5
13	Austria	4,187	11.2	2.69	1,291	30.8
14	United Kingdom	4,020	12.4	3.07	692	17.2
15	Sweden	5,247	15.6	2.96	1,842	35.1
16	Denmark	6,462	16.8	2.61	1,743	27.0
17	Finland	7,685	14.3	1.86	1,804	23.5
18	Netherlands	3,015	14.1	4.68	883	29.3
19	Norway	5,047	15.4	2.85	1,540	30.5
20	Spain	2,918	7.70	2.64	436	14.9
21	Switzerland	3,320	21.7	6.55	2,196	66.2
22	France	3,708	7.88	2.12	910	24.6
23	Germany	3,832	8.62	2.25	1,168	30.5
24	Portugal	4,079	7.34	1.80	347	8.51
25	Poland	1,633	3.94	2.41	85	5.22
26	Russian Federation	3,112	1.39	0.45	134	4.31
27	USA	4,019	8.90	2.21	1,359	33.8
28	Canada	4,470	12.4	2.78	873	19.5
29	Brazil	667	1.27	1.90	119	17.9
30	Korea Rep.	5,172	6.05	1.17	723	14.0
31	Japan	5,184	4.82	0.93	1,460	28.2
32	India	137	0.33	2.43	11	8.13
33	China	1,031	1.25	1.21	73	7.12

Table III, columns 6 and 7, compares the data on the gross domestic expenditure on research and development per capita (column 6) and per researcher (column 7), for each studied country. The lowest R&D expenditure per capita is evident for Albania (US $ 6) and the highest for Switzerland (US $ 2,196). For the countries formed from ex-Yugoslav republics, the highest expenditure can be seen for Slovenia (US $ 451) and Croatia (US $ 116), and the lowest for Bosnia and Herzegovina (US $ 15). The other countries (Serbia, FYR Macedonia and Montenegro) have very low R&D expenditure per capita. Concerning other countries, R&D expenditure per capita in India is also very low (US $ 11). The G8 countries as well as other developed countries spend significant amounts (from several hundred to several thousand US $) on R&D per capita. This certainly results in top research productivity and quality in these countries. The last column of Table III presents the data on R&D expenditure (in US $) per researcher. A comparison shows that, of all countries formed from the former Yugoslavia, the lowest R&D expenditure can be noted for Serbia and the highest for Slovenia. According to the data for all studied countries, the R&D expenditure per researcher is the lowest in Serbia (US $ 1.90×10^4) and the highest in Switzerland (US $ 66.2×10^4). In high-developed countries, G8, the expenditure is high as expected starting from US $ 17.2×10^6–30.5×10^6. The exception is Russia with expenditure of US $ 4.31×10^4.

Table IV (column 3) shows the data on the number of patents for all selected countries in the period between 2008 and 2012. Montenegro is the only country in which no patent was filed in this period. The number of patents filed ranges from 1 (Albania) to 1,146,059 (the US). For a better comparison of these data, the numbers of patents per million inhabitants are given in column 4 of the same table. Of all countries, which came into being from the former Yugoslavia, the highest number of patents per million inhabitants can be seen for Slovenia (73.4) and Croatia (19.5). For other countries of the same group, the figures are more than modest and range from 0 (Montenegro) to 4.2 (Serbia). Neighbouring countries of the former Yugoslavia have also a modest number of patents per million inhabitants – Albania (0.32) and Romania (5.32). Low numbers of patents per million inhabitants are also evident for India (4.59) and Brazil (5.17). All G8 countries, apart from the Russian Federation (with 9.25), have high number of patents per million inhabitants, going from 180 (Italy) to 3,707 (the US). All high-developed countries have high number of patents per million inhabitants.

This indicator confirms the technological level of a country. It should be mentioned that, besides the US, the following countries have more than 1000 patents per million inhabitants: Switzerland (1,105), the Republic of Korea (1,177) and Japan (1,745).

Finally, the data on the number of universities among the world top 500 ones (in 2012 and 2015) for all selected countries are given in columns 5 and 6, Table IV.

TABLE IV. Number of patents, patents per million inhabitants from 2008 to 2012, and academic ranking of world universities, according to: ARWU – The Academic Ranking of World Universities; Top 500 universities Shanghai ranking-2012.mht; Top 500 universities Shanghai Ranking-2015.mht; www.uspto.gov/go/taf/cst_all.htm

No.	Country	No. of patents 2008–2012	No. of patents (2008–2012) per mill. inhab.	ARWU 2012	ARWU 2015
1	Serbia	30	4.12	1	1
2	Croatia	85	19.5	1	
3	Bosnia & Herzegovina	5	1.30		
4	Slovenia	150	73.4	1	1
5	Macedonia, FYR	3	1.43		
6	Montenegro	0	0		
7	Albania	1	0.32		
8	Bulgaria	183	24.5		
9	Romania	114	5.32		
10	Hungary	442	44.2	2	2
11	Greece	273	24.2	2	2
12	Italy	10,886	180	20	20
13	Austria	4,161	496	7	6
14	United Kingdom	23,647	380	42	39
15	Sweden	8,212	876	11	11
16	Denmark	3,687	665	4	5
17	Finland	5,298	988	5	6
18	Netherlands	9,441	568	13	12
19	Norway	1,923	393	4	3
20	Spain	2,606	56.7	11	13
21	Switzerland	8,650	1,105	7	7
22	France	23,598	363	20	22
23	Germany	62,078	758	40	42
24	Portugal	166	15.7	3	3
25	Poland	344	8.98	2	2
26	Russian Federation	1,318	9.25	2	2
27	USA	1,146,069	3,707	149	146
28	Canada	26,246	770	22	20
29	Brazil	1,010	5.17	6	6
30	Korea Rep.	58,211	1,177	10	12
31	Japan	222,751	1,745	21	18
32	India	5,522	4.59	1	1
33	China	16,574	12.4	42	39

The list of ranked universities has been regularly updated and released by the Shanghai Institute of Education. Ranking is based on the number of staff winning Nobel Prizes, number of highly cited researchers, articles published in journals of Science and Nature, as well as on the number of articles published. These criteria are compared with the number of full-time staff members in each institution the university is composed of (collages and institutes). Among the countries formed from the former Yugoslavia, only Serbia, Croatia and Slovenia had 1 university

on this list in 2012. In 2015, Serbia and Slovenia kept their place. Of all studied countries (33), only Bosnia and Herzegovina, FYR Macedonia, Montenegro, Albania, Bulgaria and Romania have no university on the list. These data also indicate poor scientific outputs of universities and research staff in these countries.

All the member countries of G8 except the Russian Federation have from 20 (Italy) to 149 (the US) universities among the 500 best ranked ones in 2012. Two Russian universities are on the list. It is interesting that India has only 1 university on the list.

CONCLUSIONS

In this paper, a comparative analysis of the scientific production of authors from six countries, former Yugoslav republics, was given. The analysis also included seven countries, neighbours of the former Yugoslavia, several developed European countries, as well as countries from other continents. The total number of 33 countries was analyzed over the five-year period (2008–2012).

The analysis revealed that all countries, which emerged from the former Yugoslavia, except Slovenia and Croatia significantly lagged behind other selected countries. Most developed countries (G8), apart from the Russian Federation, as well as developing countries are the leaders in quality and production of scientific articles. Also, small (according to population) northern Europe countries play an important role in world science.

Research and development expenditure (% of GDP) in the countries arose from the former Yugoslavia is the lowest (except in Slovenia and Croatia) and amounts to < 0.5 %, compared with other analyzed countries. In order to improve the situation in these countries, the investment in science must be increased (at least up to 1 % of GDP) and the conditions for research and development including infrastructure should be improved.

ИЗВОД

УПОРЕДНА АНАЛИЗА НАУЧНЕ ПРОДУКЦИЈЕ ДРЖАВА НАСТАЛИХ ИЗ РЕПУБЛИКА БИВШЕ ЈУГОСЛАВИЈЕ И НЕКИХ ДРУГИХ ЗЕМАЉА, ЗА ПЕРИОД 2008–2012.

ВЕРИЦА РОГЛИЋ-КОРИЦА и СЛОБОДАН К. МИЛОЊИЋ

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Дискутовани су научни доприноси шест држава (некадашњих република бивше Југославије): Србије, Хрватске, Словеније, Босне и Херцеговине, Македоније и Црне Горе. Ради упоређења са другим државама, дати су и подаци за седам држава (Албанија, Грчка, Бугарска, Румунија, Мађарска, Аустрија и Италија) суседа бивше Југославије. Такође су наведени и подаци групе Г8 држава (Уједињено Краљевство, Канада, САД, Француска, Италија, Немачка, Јапан и Русија) као и неких европских земаља чији је број становника сличан броју становника некадашњих република бивше Југославије. Ради потпунијег сагледавања научног доприноса појединих држава наведени су подаци о научној продукцији неколико развијених европских држава као и држава са осталих континената. Анализа обухвата укупно 33 државе и урађена је на основу различитих

индикатора, а односи се на петогодишњи период (2008–2012.). Подаци су сакупљени из међународних база података.

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