

Publications from Serbia in the Science Citation Index Expanded: a bibliometric analysis

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Abstract This paper presents a bibliometric analysis of articles from the Republic of Serbia in the period 2006–2013 that are indexed in the Thomson Reuters SCI-EXPANDED database. Analysis included 27,157 articles with at least one author from Serbia. Number of publications and its characteristics, collaboration patterns, as well as impact of analyzed articles in world science will be discussed in the paper. The number of articles indexed by SCI-EXPANDED has seen an increase in terms of Serbian articles that is considerably greater than the increase in number of all articles in SCI-EXPANDED. Researchers from Serbia have been involved in researches presented in several articles which have significant impact in world science. Beside indicators which take into account number of publications of certain type and number of citations, the analysis presented in this paper also takes authorship into consideration. The most cited analyzed articles have more than ten authors, but there were no first and corresponding authors from Serbia in these articles

Keywords Serbia · Web of Science · Research trends · Collaborations · Impact

Introduction

Bibliometric analysis is an useful method for characterizing scientific research (Moravcsik 1985; Fu and Ho 2013) which can be used for making decisions regarding the further development of science (Lucio-Arias and Leydesdorff 2009). Moreover, bibliometric

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analyses have been used for analyzing and comparing the scientific-research outputs of several countries (King 2004). Although bibliometric indicators are not a perfect measure for evaluation of scientific research, their use is widespread worldwide (Moed 2006; Adams 2009), and bibliometric analyses have been based on bibliometric indicators very often (Wang et al. 2010; Ho 2013). Furthermore, trends in a certain scientific field or the importance of the researcher, journal, scientific conference, scientific institution or a certain country within the world science community can be determined based on bibliometric indicators (Wang et al. 2010). Moreover, analyses of the scientific-research production of countries belonging to all continents have been studied using bibliometric indicators for example Russia (Markusova et al. 2009), the Netherlands (Moed et al. 1995), Estonia (Allik 2008), China (Fu et al. 2011; Fu and Ho 2013), Brazil (Leta and Chaimovich 2002), the Republic of South African (Jeenah and Pouris 2008), and Morocco (Bouabid and Martin 2009).

This paper analyses journal publications contributed by Serbian researchers in the Science Citation Index Expanded (SCI-EXPANDED) database from 2006 to 2013. Since 2006, when the Republic of Serbia became an independent country, a few recognitions have been gained to this small European country for its scientific-research outputs. Thomson Reuters gave the status of *rising star* several times to the Republic of Serbia for achieving the highest percent increase in total citations in multiple fields (<http://archive.sciencewatch.com/dr/rs/11jul-rs/>, <http://archive.sciencewatch.com/dr/rs/10jan-rs/>, <http://archive.sciencewatch.com/dr/rs/09jan-rs/>). Moreover, the Serbia's biggest university (University of Belgrade) was included in the top 500 universities according to the Academic Ranking of World Universities 2012; in the best 400 universities in 2013 and 2014; in the best 150 and 200 universities according to Academic Ranking of World Universities in mathematics in 2013 and 2014, respectively. It is approved that the productivity of Serbian researchers during the past few years has been very good, taking into account the number of researchers in the country, its GDP and percentage of GDP spent on research (Ivanović and Ho 2014).

Although the bibliometric analysis presented in this paper is not the first analysis of Serbian scientific publications, it is different than all previous researches. A bibliometric analysis of independent publications from Serbia in the SCI-EXPANDED database was published in 2014 (Ivanović and Ho 2014). That analysis included 14,293 articles with all authors from Serbia published in the period 2006–2012. Conclusions drawn from that analysis can be different in some aspects than conclusions drawn from a bibliometric analysis of all scientific-research articles published by at least one author from Serbia. Thus, conclusions drawn from the analysis presented in this paper will be compared with previous research. Furthermore, a research about citations of papers published by Serbian researchers was published in 2009 (Filipi-Matutinović et al. 2009). That research was based on the citation of papers from 1487 Serbian researchers from the SCI-EXPANDED and from a Serbian citation base that stores only papers published in journals based in Serbia. Moreover, the research was limited to papers published in the period 2003–2008. Additionally, Serbia has much more registered researchers than 1487, meaning the research excluded papers from a lot of researchers from Serbia. Moreover, there are several published bibliometric analyses of journals based in Serbia (Popović et al. 2012; Šipka 2012; Jaćimović et al. 2010), as well as several published bibliometric analyses of published results from a selection of distinguished researchers from Serbia (Šipka 2005; Filipi-Matutinović 2007). Also, a bibliometric analysis of publications from Serbia in the nanoscience scientific field was published in 2009 (Ševkušić and Uskoković 2009). Also, there are several published researches dealing with published results of the Republic of

Croatia, which until 1991 belonged to the former Yugoslavia as well as the Republic of Serbia (Bencetić Klaić and Klaić 2004; Borić and Strujić 2006; Bencetić Klaić and Klaić 1997; Klaić 1997). Also, an interesting research about effects of civil war on scientific cooperation in the republics of the former Yugoslavia and the province of Kosovo was published in 2010 (Jovanović et al. 2010).

Although a sequence of bibliometric analyses including papers from Serbia have been published prior to the research presented in this paper, this research is different than all previous researches because it uses a different data set, methodology and bibliometric indicators. Beside indicators which take into account number of publications of certain type and number of citations, the analysis presented in this paper also takes authorship into consideration.

Methodology

Data set used in this research was obtained from Thompson Reuters Web of Science, the online version of the SCI-EXPANDED, on 06th August 2014. An advanced search by field Country (CU) using the keyword “Serbia” was conducted and the retrieved results were limited to results published during the period 2006–2013. In total, 35,064 documents were retrieved as a result of that search. Retrieved results are additionally refined by excluding the country “Serbia Monteneg”, because it contains word Serbia in its name. After this step, 34,207 documents were remained in the list of results. Furthermore, ten document types were found in the total 34,207 publications from 2006 to 2013. Article (27,167) was the most-frequently document type comprising 79 % of the total publications, followed by meeting abstracts (5266; 15 %), and proceedings papers (1258; 3.7 %). The list of documents also included reviews (858), editorial materials (385), letters (381), corrections (77), news items (44), biographical-items (29), and book chapters (10). As journal articles represented the majority of document types that also presented whole research topics, they were used for further analysis. Documents’ information about 27,167 articles including names of authors, titles, years of publications, source journals publishing the articles, contact addresses, and number of citations for each article for every year were downloaded in the Microsoft Excel file format.

After downloading data, a consolidation of data concerning contact addresses was performed in order to enable better determining institutions’ names to which articles’ authors are affiliated.

Lately the contribution of authors was diluted, because multiple-authorship has been increased (National Science Board 2010). Beside indicators which take into account number of publications of certain type or number of citations, the analysis presented in this paper takes authorship into consideration. Creation of authorship list can be based on contribution, alphabetical order, or reverse seniority, but the approach most often used is ordering by contribution, especially for articles with a few authors (Tscharntke et al. 2007). The first author usually makes the most contribution, and should receive a greater proportion of the credit (Riesenbergh and Lundberg 1990; Marušić et al. 2004). A corresponding author, also known as responsible author supervises the planning and execution of the study and the writing of the article (Burman 1982). The research presented in this paper analyse the first and corresponding authorship. In the Thompson Reuters Web of Science citation base, corresponding author is labelled as “reprint author”. In single author articles where authorship is unspecified, the single author is classified as the first author and

as corresponding author (Ho 2012). Analogous to this, in single institute articles, the single institute is classified as the first author institute and as the corresponding author institute.

Results and discussion

A total of 27,167 journal articles published in the period 2006–2013 by at least one author from Serbia in SCI-EXPANDED were found. Almost all of those articles (25,814; 95 %) were published in English. Non-English languages also appeared, including Serbian, Croatian, German, Russian, French, Hungarian, Portuguese, Spanish, Czech, Slovak, Slovene, Chinese, and Italian. Hereinafter, number of publications and its characteristics, collaboration patterns, as well as impact of analyzed articles in world science will be discussed.

Distribution and characteristics of publications

The production of articles published by Serbian researchers during the period 2006–2013 has achieved a higher increase than the increase in number of all articles in the SCI-EXPANDED database in this period. In this period, the annual number of published journal articles originating from Serbia increased more than fivefold, the number of articles increased from 934 articles published in 2006–4855 in 2013 (Table 1). On the other side, the number of all articles in the SCI-EXPANDED database increased from 1,294,616 in 2006 to 1,720,565 in 2013 which is in accordance with the slight increase of the number of journals indexed by SCI-EXPANDED from 6166 journals in 2006, to 8539 journals in 2013. Hence, the number of articles indexed by SCI-EXPANDED has seen an increase in terms of Serbian articles that is considerably greater than the increase in number of all articles in SCI-EXPANDED. There are a few important facts for explanation of this sudden increase in number of Serbian articles which are discussed hereinafter.

The reason for sudden increase in Serbian articles between 2006 and 2007 is the change in name of Serbia, which occurred in June 2006. Up to this point, Serbia had been part of

Table 1 Number of articles

Years	TP	AU	AU/TP	NR	NR/TP	PG	PG/TP
2006	934	4966	5.3	22,802	24	7860	8.4
2007	2261	12,727	5.6	56,507	25	18,393	8.1
2008	2684	14,539	5.4	67,280	25	21,239	7.9
2009	3241	19,356	6.0	86,507	27	26,468	8.2
2010	3629	129,159	36	102,635	28	32,718	9.0
2011	4212	354,546	84	120,716	29	38,454	9.1
2012	5351	636,519	119	161,992	30	51,298	9.6
2013	4855	459,384	95	161,087	33	48,183	9.9
Total	27,167	1,631,196		779,526		244,613	
Average			60		29		9.0

TP number of Serbian articles, *AU* number of authors, *NR* cited reference count, *PG* page count, *AU/TP*, *NR/TP*, and *PG/TP* average of authors, references, and pages in an article

Serbia and Montenegro, which comprised the Republic of Serbia and the Republic of Montenegro. There are 788 articles published in 2006 that are according to their addresses tied to the former Serbia and Montenegro. Although, some of those 788 articles were written by researchers that were employed in scientific institutions that is today the Republic of Serbia, those articles have been excluded from analysis presented in this paper as it is explained in the “(Methodology)” section.

Furthermore, the increase of Serbian articles in the latter period of 2006–2013 in terms of scientific production could have been considerably promoted by the rule book for evaluation of scientific-research results prescribed by Ministry of education, science and technological development of the Republic of Serbia, which was issued in 2008 (www.mpn.gov.rs/images/content/nauka/pravna_akta/PRAVILNIK_o_zvanjima.pdf).

That rule book requires that researchers must have articles published in journals listed on the JCR list for the promotion to scientific positions. In addition, the increase in number of articles was influenced by the fact that several journals based in Serbia have in recent years appeared on the JCR list: *Vojnosanitetski Pregled*, *Archives of Biological Sciences*, *Srpski Arhiv Za Celokupno Lekarstvo*, *Journal of the Serbian Chemical Society*, etc. Those journals published in the period 2006–2013 a considerable number of articles whose authors were from Serbia. However, there is a slight decrease in number of Serbian articles between 2012 and 2013. Serbian researchers published almost 10 % less articles in 2013 than in 2012 according to analyzed data set. The one reason for this exception could be that filling of SCI-EXPANDED database with articles published in 2013 was not yet completed on 06th August 2014. However, the next few years will show us whether this is just exception of further trend of number of Serbian articles in SCI-EXPANDED database.

Besides increasing a number of articles, the average article length fluctuated slightly, with an overall increase in the average length from 8.4 pages in 2006 to 9.9 pages in 2013. The average number of references per paper rose from 24 in 2006 to 33 in 2013. The average number of authors was 5.3, and the highest number of authors of an article is 3220.

Web of science categories and publications’ topics

The information of Web of Science categories have used to identify the strength of discipline of China (Fu and Ho 2013) and Serbia (Ivanović and Ho 2014). Table 2 shows the distribution of articles in the top ten Web of Science categories according to the number of Serbian articles. A total of 2183 articles (8 % of all Serbian articles) were published in the

Table 2 Top ten productive Web of Science categories

Web of Science category	TP	(%)
General and internal medicine	2183	8.0
Applied mathematics	1523	5.6
Multidisciplinary chemistry	1323	4.9
Multidisciplinary materials science	1203	4.4
Mathematics	1149	4.2
Chemical engineering	1091	4.0
Physical chemistry	982	3.6
Electrical and electronic engineering	980	3.6
Biology	962	3.5
Multidisciplinary physics	940	3.5

TP number of Serbian articles, % percentage of articles belonging to the certain category to all analyzed articles

category general and internal medicine. It presents 1.7 % of all articles in SCI-EXPANDED belonging to this category. Since the population of Serbia only accounts for little more than 0.1 % of the global population, the productivity of Serbia in the category general and internal medicine can be considered outstanding. Amongst ten listed categories, two categories belong to the field of mathematics (applied mathematics; mathematics), and three belong to the field of chemistry (multidisciplinary chemistry; chemical engineering; physical chemistry). There is also the category multidisciplinary materials science that overlaps with the field of chemistry. If some other taxonomy of scientific categories were be used instead of the Web of Science categories taxonomy, conclusions concerning what most researchers from Serbia studied in the period 2006–2013 and in what field they mostly contributed to in world science might be different.

The title and the author keywords, provides a reasonably detailed picture of the article's theme. Statistical analysis of words in title, and author keywords has been developed only in recent years, and has proved to be significant in monitoring the development of science and programs (Li et al. 2009; Ho et al. 2010). Including words in title and author keywords together could minimize limitations, such as the uncompleted meaning of single words in title, the small sample size for author keywords (Fu and Ho 2013). A word statistical analysis technique using words in the article title and author keywords is also used to identify the research focus of Serbia. The most frequently used words in analyzed articles' titles ordered decreasingly by frequency of occurrence are: Serbia, patients, properties, influence, activity, system, treatment, etc. Furthermore, the most frequently used articles'

Table 3 Top twelve productive Web of Science journals

Journals	TP (%)	IF ₂₀₁₃	Web of Science category	Country
Vojnosanitetski Pregled	909 (3.3)	0.269	General and internal medicine	Serbia
Archives of Biological Sciences	706 (2.6)	0.607	Biology	Serbia
Srpski Arhiv Za Celokupno Lekarstvo	656 (2.4)	0.169	General and internal medicine	Serbia
Journal of the Serbian Chemical Society	562 (2.1)	0.889	Multidisciplinary chemistry	Serbia
Hemijska Industrija	471 (1.7)	0.562	Chemical engineering	Serbia
Technics Technologies Education Management-TTEM	301 (1.1)	N/A	Multidisciplinary engineering	Bosnia and Herzegovina
Acta Veterinaria-Beograd	284 (1.0)	0.133	Veterinary sciences	Serbia
Metalurgia International	283 (1.0)	N/A	Metallurgy and metallurgical engineering	Romania
Applied mathematics and Computation	278 (1.0)	1.6	Applied mathematics	USA
Healthmed	261 (1.0)	N/A	General and internal medicine	Bosnia and Herzegovina
Genetika-Belgrade	234 (0.86)	0.492	Agronomy Genetics and heredity	Serbia
Thermal Science	207 (0.76)	0.962	Thermodynamics	Serbia

TP total published articles, % percentage of articles belonging to the certain journal to all analyzed articles, IF₂₀₁₃ impact factor in 2013, N/A not available

keywords ordered decreasingly by frequency of occurrence are: Serbia, diagnosis, antimicrobial activity, oxidative stress, treatment outcome, risk factors, etc. Dominant words among those most frequently used in titles and keywords were words often used in the scientific field of medicine. Also, present were words that are frequently used in the scientific fields of chemistry, mathematics and biology. The distribution of the most frequently used words was consistent with the category information shown in Table 2.

Distribution of journal

Table 3 shows the distribution of articles in the top 12 journals, with 200 or more published articles from Serbia. The value of the indicator IF_{2013} for each journal was obtained from JCR for 2013. The journal with the most published articles was *Vojnosanitetski Pregled*, which published 909 articles, 3.3 % of all analyzed articles. *Vojnosanitetski Pregled* falls into the category of general and internal medicine and had a 2013 impact factor of 0.269. In third place was *Srpski Arhiv Za Celokupno Lekarstvo*, which also belonged to the category of general and international medicine and had a 2013 impact factor of 0.169. The category general and internal medicine contained journals with a much higher average 2013 impact factor of 2.7. Eight of the top twelve journals shown in Table 3 were based in Serbia, and only four journals *Technics Technologies Education Management-Ttem*, *Metalurgia International*, *Applied mathematics and Computation*, *Healthmed* were not based in Serbia. Headquarters of journals *Technics Technologies Education Management-Ttem* and *Healthmed* are in the Serbian neighbouring country of Bosnia and Herzegovina, and headquarter of *Metalurgia International* is in the Serbian neighbouring country of Romania. Previous three journals have been marked as predatory journals by some author (<http://scholarlyoa.com/2013/03/07/report-details-predatory-practices-of-two-bosnian-journals/>, <http://dropproxy.com/u/5AE/metalurgia/novo/index.html>) and have been removed from JCR list in 2013. The journal *Applied mathematics and Computation* is based in USA, it has the highest IF_{2013} of all listed journals and belongs to the scientific category applied mathematics. Recognition of Serbian scientific results in the category of mathematics was approved by the fact that for the first time, the Serbian biggest university (University of Belgrade) was ranked in 2013 within the top 100–150 ARWU in the field of mathematics.

Inter-institutional collaboration

Over the past few decades, there has been an increase in the number of multi-author papers within scientific journals (King 2000; National Science Board 2010). Collaboration had positive effects on increasing the quantity of publication (Cho et al. 2010). A total of 1473 articles (5.4 %) of the 27,167 analyzed articles were written by single authors, 3153 (12 %) by two authors, 4333 (16 %) by three, 4554 (17 %) by four, 4251 (16 %) by five, 3133 (12 %) by six, and 2654 (10 %) by seven authors. There were 557 (2.1 %) articles written by more than 1000 authors per article: 43 such articles in 2010; 128 articles in 2011; 221 articles in 2012; and 165 articles in 2013. Thus the average number of authors per article from 2010 became unbelievable high. In 94 % of those 557 articles the first author is G. Aad from University of Freiburg at Germany (269, 48 % of 557 articles) or S. Chatrchyan from Yerevan Physics Institute of Armenia (256, 46 %). However, there were no first and corresponding authors from Serbia in these 557 articles. Collaboration type of an article was determined from the addresses of the authors. As already said a consolidation of data concerning contact addresses was performed in order to enable better determining

institutions' names to which articles' authors are affiliated. The articles were classified into six types based on institutions' names and countries:

1. TP: the number of total articles of an institution;
2. SP: the number of single institution articles; authors are from same institution;
3. ICP: the number of international collaborative articles; authors are from institutions based in different countries;
4. NCP: the number of multi-authors articles; authors are from Serbia, but not from the same institution;
5. FP: the number of first author articles; the first author is from the certain institution for analysis;
6. RP: the number of corresponding author articles; the corresponding author is from the certain institution for analysis.

Table 4 shows the distribution of publications from Serbia by seven most productive scientific institutions with 500 or more published articles. The column TP R (%) show positions of the certain institution in the list of Serbian institutions ordered by the certain indicator and the percentage of the number of articles in the total number of analyzed articles. Researchers affiliated to those seven institutions published 93 % of all analyzed articles. Other columns where the header contains R (%) following the abbreviation for an indicator show position of certain institution in the list of Serbian institutions ordered by the certain indicator and the percentage of the number of articles of the certain type in the total number of articles from the certain institution. For example, the value of the first line in column SP R (%) is one (26), which means that the University of Belgrade took first place according to the number of single institution articles and 26 % of all articles are published by all authors affiliated at this university. Conclusions about distribution of publications per scientific institutions are very similar to conclusions presented in the paper which analyzed just Serbian independent articles (Ivanović et al. 2014). According to the values of the indicators shown in Table 4, first place is awarded to the University of Belgrade, which is the largest science-education institution in Serbia consisting of 31 faculties and 11 scientific institutes. During the period 2006–2013, this university published 55 % of the analysed articles. Furthermore, the University of Belgrade took first

Table 4 Top seven productive Serbian institutions

Institutions	TP	TP R (%)	SP R (%)	ICP R (%)	NCP R (%)	FP R (%)	RP R (%)
University of Belgrade, Serbia	14,961	1 (55)	1 (26)	1 (40)	1 (34)	1 (57)	1 (57)
University of Novi Sad, Serbia	3486	2 (13)	2 (35)	2 (32)	2 (33)	2 (66)	2 (65)
University of Nis, Serbia	2424	3 (8.9)	3 (36)	3 (29)	4 (35)	3 (66)	3 (66)
University of Kragujevac, Serbia	1825	4 (6.7)	4 (25)	4 (31)	5 (43)	4 (60)	4 (60)
Clinical Center of Serbia, Serbia	1445	5 (5.3)	6 (12)	5 (21)	3 (67)	5 (43)	5 (41)
Serbian Academy of Sciences and Arts, Serbia	755	6 (2.7)	5 (25)	6 (39)	7 (36)	6 (51)	6 (53)
Military Medical Academy, Serbia	566	7 (2.1)	7 (12)	8 (19)	6 (69)	7 (41)	7 (40)

TP total articles, SP single institute articles, ICP internationally collaborative articles, NCP nationally collaborative articles, FP first author articles, RP corresponding author articles, R rank, % percentage in an institute

Table 5 Distribution of international collaborative articles per countries

Country	TP	TP R (%)	FP R (%)	RP R (%)
Germany	1959	1 (7.2)	1 (2.3)	1 (2.4)
USA	1909	2 (7.0)	2 (1.8)	2 (1.9)
Italy	1542	3 (5.7)	3 (1.2)	3 (1.2)
UK	1541	4 (5.7)	4 (1.0)	4 (1.1)
France	1290	5 (4.7)	6 (0.63)	6 (0.66)
Greece	1123	6 (4.1)	11 (0.49)	9 (0.50)
Spain	1119	7 (4.1)	13 (0.48)	11 (0.49)
Austria	1015	8 (3.7)	12 (0.48)	13 (0.49)
Switzerland	1013	9 (3.7)	14 (0.47)	14 (0.48)
Poland	989	10 (3.6)	21 (0.25)	21 (0.25)
Czech Republic	971	11 (3.6)	24 (0.21)	25 (0.20)
China	957	12 (3.5)	8 (0.58)	8 (0.55)
Russia	949	13 (3.5)	27 (0.20)	23 (0.21)
Slovenia	898	14 (3.3)	7 (0.59)	7 (0.61)
Hungary	855	15 (3.1)	22 (0.24)	21 (0.25)
Turkey	810	16 (3.0)	20 (0.29)	20 (0.29)
Croatia	774	17 (2.8)	15 (0.44)	15 (0.44)
Portugal	741	18 (2.7)	33 (0.14)	32 (0.14)
Romania	736	19 (2.7)	18 (0.33)	18 (0.33)
Brazil	727	20 (2.7)	40 (0.074)	40 (0.077)
Armenia	677	21 (2.5)	5 (0.94)	5 (0.87)
Belgium	637	22 (2.3)	17 (0.34)	17 (0.34)
Netherlands	633	23 (2.3)	19 (0.30)	19 (0.31)
Sweden	606	24 (2.2)	24 (0.21)	24 (0.21)
Canada	605	25 (2.2)	16 (0.36)	16 (0.35)
Taiwan	589	26 (2.2)	55 (0.029)	55 (0.026)
Belarus	585	27 (2.2)	62 (0.011)	60 (0.011)
Democratic Republic of Georgia	576	28 (2.1)	72 (0.0037)	68 (0.0037)
Colombia	574	29 (2.1)	58 (0.015)	60 (0.011)
Bulgaria	558	30 (2.1)	30 (0.19)	28 (0.19)
Australia	555	31 (2.0)	23 (0.22)	27 (0.20)
India	546	32 (2.0)	27 (0.20)	29 (0.19)
Japan	538	33 (2.0)	31 (0.18)	30 (0.18)
Bosnia and Herceg	529	34 (1.9)	9 (0.54)	9 (0.50)
Mexico	522	35 (1.9)	52 (0.033)	53 (0.030)
Slovakia	517	36 (1.9)	33 (0.14)	34 (0.13)
Denmark	509	37 (1.9)	32 (0.14)	32 (0.14)

TP total articles, % percentage of articles belonging to the certain country to all analyzed articles, *FP* first author articles, *RP* corresponding author articles

place by all remaining indicators shown in Table 4. The second place by all indicators was taken by the University of Novi Sad. The third place was taken by the University of Nis by all indicators except the category number of articles that were the result of cooperation

between Serbian institutions (NCP). According to the number of articles that were the result of cooperation between Serbian authors which are not from the same institution, third place belonged to the Clinical Center of Serbia, which is based in Belgrade and its researchers cooperate intensively with researchers affiliated with the Medical Faculty of the University of Belgrade. Therefore, most of the articles written by researchers from the University Centre of Serbia had been written in cooperation with researchers from the University of Belgrade. According to the ratio of single institution articles, first author articles and corresponding author articles in all published articles by institution (percentages in the brackets), University of Novi Sad and University of Nis are even better than University of Belgrade, but according to the number of articles of those types these universities are far away from the University of Belgrade. With respect to the percentage of internationally collaborative articles (ICP), the first and second place was awarded to the University of Belgrade and Serbian Academy of Science and Arts, respectively.

International collaboration

According to Table 4 about one-third of all articles (8906 of 27,167 articles) are single institution articles (SP), and about two-thirds of all articles (18,261 articles) publish collaborative research (ICP and NCP). A half of these collaborative articles (9783 of 18,261 articles) are results of collaboration of researchers affiliated at Serbian institutions (NCP), and a half of collaborative articles (8478 articles) are results of collaboration between Serbian researchers and researchers from abroad (ICP). Table 5 shows the distribution of those internationally collaborative articles (ICP) by thirty-seven countries which researchers published more than 500 collaborative articles with Serbian researchers in the period 2006–2013.

The most productive countries according to the number of published articles in collaboration with Serbian researchers are Germany and USA, but there are more published articles with Germany researchers having leading role by Serbian researchers (FP and RP). However, percentage of articles with leading role by Serbian researchers is pretty low for all shown countries. The Republic of Serbia is located in Europe and nine of top ten countries shown in Table 5 are also located in Europe, but there is no any neighbouring Serbian country in top ten countries. More collaboration with non-adjacent countries than neighbouring countries can be explained with economic and social development, research and development expenditure of these countries, and also with the fact that the Yugoslav civil wars (http://en.wikipedia.org/wiki/Yugoslav_Wars) broke a lot of collaboration in research domain between ex-Yugoslav countries (Serbia, Croatia, Macedonia, Montenegro, Slovenia, Bosnia and Herzegovina). Unfortunately, those broken collaboration are not yet fully repaired.

Impact in world science

The list of most productive journals according to the number of analyzed articles (Table 3) contains three journals (*Technics Technologies Education Management-Ttem*; *Metalurgia*; *Healthmed*) marked as predatory journals by some author (<http://scholarlyoa.com/2013/03/07/report-details-predatory-practices-of-two-bosnian-journals/>, <http://dropproxy.com/u/5AE/metalurgia/novo/index.html>). Previous three journals have been removed from JCR list in 2013, because average quality of published articles in those journals has become unacceptable low. Thus, the quality of articles published by these journals in the period 2006–2013 is under question.

Besides the journal *Healthmed* which has been removed from the JCR in 2013, the list contains two journals (*Vojnosanitetski Pregled*; and *Srpski Arhiv Za Celokupno Lekarstvo*) belonging to WoS category general and internal medicine placed amongst the 15 % of journals with the weakest impact on world research community according to the value of IF_{2013} . These two journals are both based in Belgrade, the capital city of Serbia and as such, the names of the journals are in Serbian. A significant percentage of all published articles in these journals were written by at least one researcher from Serbia: 909 of 934 articles, i.e., 97 % of articles in *Vojnosanitetski Pregled*; 656 of 704 articles, i.e., 93 % of articles in *Srpski Arhiv Za Celokupno Lekarstvo*. Most articles in these journals were in English, but there were also articles in Serbian language that were undoubtedly less accessible to the global scientific community. On one side, Serbia—with little more than 0.1 % of the global population—published 1.7 % of all publications in the category of general and international medicine during the period 2006–2013; on the other hand, over 83 % of these articles from Serbia were published in journal marked as a predatory journal which has been removed from JCR in 2013 and in two journals with small impact factors, where the largest number of published articles was written by researchers from Serbia. Some of these articles were written in Serbian. These facts indicate that although Serbia shows considerable productivity in terms of articles in the category of general and internal medicine, a significant number of these articles did not influence the research conducted by researchers from other countries in this category. Other facts also support this argument. More than 98 % of 2183 articles published in the category general and internal medicine had less than ten citations and more than 61 % of these articles were without any citations. However, Serbian researchers have been involved in several highly cited articles in this category. The most cited article in this category published by at least one researcher from Serbia has 1684 citations on 1st December 2014 and it is 23rd most cited articles of 128,986 articles published in the category of general and international medicine in SCI-EXPANDED in the period 2006–2013. Also, the next two most cited articles from Serbia have more than 500 citations and belong to the top 0.3 % articles in this category; the next three articles have more than 100 citations and belong to the top 3 % articles; the next six articles have more than 50 citations and belong to the top 5 % articles. Thus, some articles published by at least one researcher from Serbia have significant impact in world science in the general and internal medicine category.

The most productive institution is University of Belgrade (Table 4). Quality of scientific results of this university reached a few recognitions. This university was included in the top 500 and the top 400 universities as listed on the Academic Ranking of World Universities in 2012 (www.shanghairanking.com/ARWU2012.html) and in 2013 (www.shanghairanking.com/ARWU2013.html), respectively. Furthermore, it was included in the top 150 and in the top 200 universities according to the Academic Ranking of World Universities in mathematics in 2013 (www.shanghairanking.com/SubjectMathematics2013.html) and in 2014 (www.shanghairanking.com/SubjectMathematics2014.html), respectively.

Characteristics of most cited articles

Citations of a publication is not a direct measure of quality and significance, but it reflects the visibility and impact of the publication on the scientific community (Furlan and Fehlings 2006; Baltussen and Kindler 2004). As already mentioned, Thomson Reuters gave the status of *rising star* several times to the Republic of Serbia for achieving the highest percent increase in total citations in multiple fields (<http://archive.sciencewatch.com/dr/rs/11jul-rs/>, <http://archive.sciencewatch.com/dr/rs/10jan-rs/>, <http://archive.sciencewatch.com/dr/rs/10jan-rs/>, <http://archive.sciencewatch.com/dr/rs/10jan-rs/>).

sciencewatch.com/dr/rs/09jan-rs/). Figure 1 approves the conclusion of the research made by Figg and colleagues: “The number of times an article was cited correlated significantly with the number of authors and the number of institutions” (Figg et al. 2006). The highest citation is for international collaboration articles with corresponding authors which are not from Serbia. Furthermore, number of citations per article is much higher for international collaboration articles than Serbia independent articles. Citation life cycles curves show similar fluctuation for all groups of articles shown in Fig. 1.

Table 6 shows articles published by at least one researcher from Serbia in the period 2006–2013 that, up to the end of 2013, had been cited more than 300 times ($TC_{2013} > 300$). Apart from the value of indicators TC_{2013} , C_0 , C_{2013} , and TCPY (listed in brackets), Table 6 also shows the positions that listed articles take according to the value of these indicators. Below the table is explanation of meaning of these indicators. Although the article with the highest TC_{2013} is published by Hudes and colleagues, according to the year of publication and all shown indicators in Table 6, the article published by Aad and colleagues might become the highest impact article published at least one author from Serbia in the near future. Four of eight articles belong to the Medicine scientific fields, and three articles belong to Physics scientific field. These articles have significant impact on scientific community and researchers from Serbia have been involved in researches presented in these articles. However, each of these eight articles has more than ten authors, and the first authors and corresponding authors are not from Serbia. Thus, the contribution of Serbia was therefore significantly diluted in these articles.

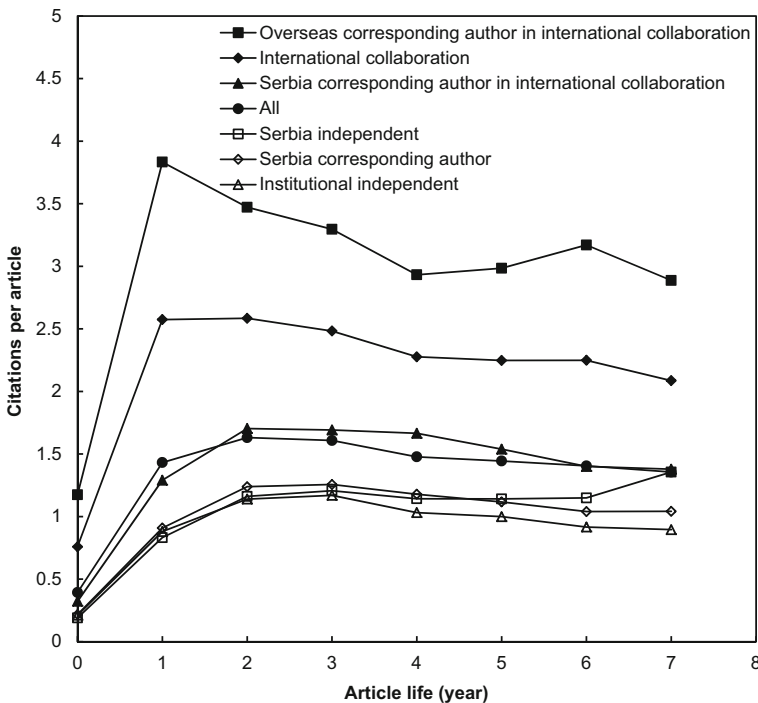


Fig. 1 Citations per article

Table 6 Top eight cited articles

Rank (TC ₂₀₁₃)	Rank (C ₀)	Rank (C ₂₀₁₃)	Rank (TCPY)	Article title	References
1 (1494)	24 (29)	4 (222)	3 (213)	Temsirolimus, interferon alfa, or both for advanced renal-cell carcinoma	Hudes et al. (2007)
2 (1161)	4 (134)	1 (1027)	1 (581)	Observation of a new particle in the search for the standard model Higgs boson with the ATLAS detector at the LHC	Aad et al. (2012)
3 (1096)	5 (120)	3 (976)	2 (548)	Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC	Chatrchyan et al. 2012
4 (749)	532 (3)	6 (128)	6 (93.6)	Chemotherapy with preoperative radiotherapy in rectal cancer	Bosset et al. (2006)
5 (426)	856 (2)	10 (93)	12 (60.9)	Cisplatin, fluorouracil, and docetaxel in unresectable head and neck cancer	Vermorken et al. (2007)
6 (365)	27 (26)	7 (121)	7 (91.3)	Bandgap opening in graphene induced by patterned hydrogen adsorption	Balog et al. (2010)
7 (362)	53 (16)	18 (56)	15 (51.7)	An increased micronucleus frequency in peripheral blood lymphocytes predicts the risk of cancer in humans	Bosset et al. (2006)
8 (317)	3 (221)	9 (96)	4 (159)	Combined results of searches for the standard model Higgs boson in pp collisions at root $s = 7$ TeV	Chatrchyan et al. 2012

TC₂₀₁₃ total citations from its publication to the end of 2013, C₀ total citations in publication year, C₂₀₁₃ total citations in 2013, TCPY TC₂₀₁₃ per year

Conclusions

This paper presented a bibliometric analysis of 27,157 journals’ articles published by at least one author from the Republic of Serbia in the period 2006–2013 and indexed in the Thomson Reuters SCI-EXPANDED database. The analysis showed that the number of articles indexed by SCI-EXPANDED has seen an increase in terms of Serbian articles that is considerably greater than the increase in number of all articles in SCI-EXPANDED. Reasons for this significant increase include change of name Serbia and Montenegro in the Republic of Serbia in the middle of 2006; introduction of a new rule book for evaluation prescribed by Ministry of Education, Science and Technological Development of the Republic of Serbia in 2008; and the fact that several new journals based in Serbia which published a considerable number of articles from Serbia started to be indexed in SCI-EXPANDED during the analyzed period 2006–2013. According to the number of articles and statistical analyses of words used in titles and keywords, Serbian researchers mostly contributed to the category general and internal medicine. Only 5.4 % of analyzed articles are single author articles, and the rest of analyzed articles are collaborative articles including 557 (2.1 %) collaborative articles with more than 1000 authors per articles, but without leading roles of Serbian researchers in those articles. Furthermore, the University of Belgrade dominated in scientific articles publication in Serbia, which is not surprising, as it is the biggest institution, and this university was included in the top 500 universities by Academic Ranking of World Universities which is a good recognition for the quality of scientific results of this university. The significant number of articles did not influence the research conducted by researchers

from other countries taking into account number of citations of those articles and the fact that they are published in Serbian journals with weak impact factor or journals which have been marked as predatory journals by some authors. On the other side, researchers from Serbia have been involved in researches presented in several articles which have significant impact in world science, but without leading role (the first or corresponding author). Also, Thomson Reuters gave the status of rising star several times to Serbia for achieving the highest percent increase in total citations in multiple fields.

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