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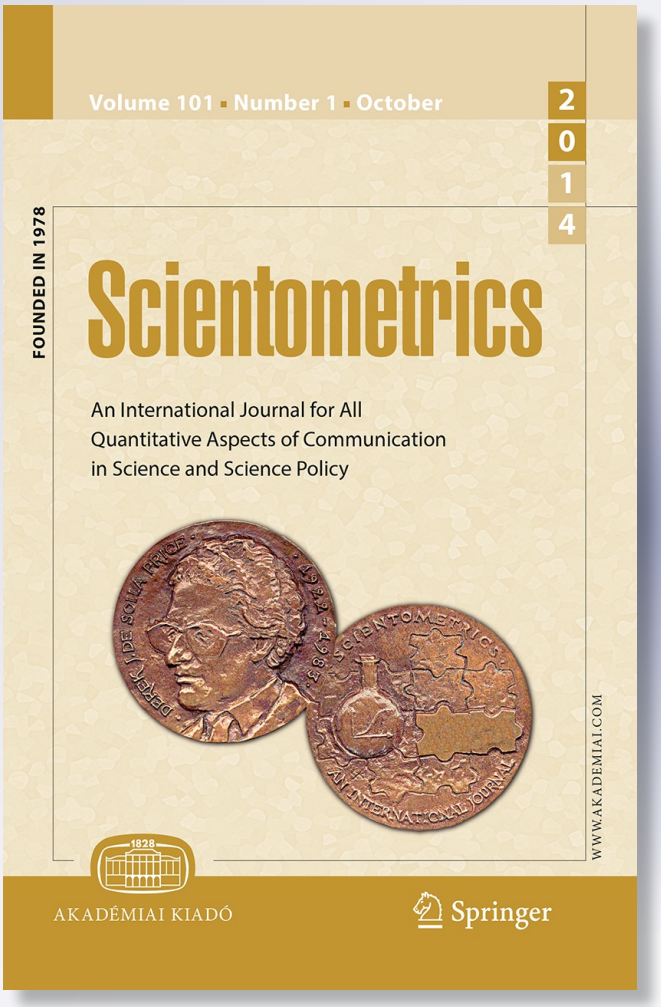

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Independent publications from Serbia in the Science Citation Index Expanded: a bibliometric analysis

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Abstract This paper presents a bibliometric analysis of articles from the Republic of Serbia in the period 2006–2012 that are indexed in the Thomson Reuters SCI-EXPANDED database. The Republic of Serbia is a small country in Europe with about seven million citizens that became an independent country in 2006. Since 2006, Serbian science has achieved some recognition. Analysis included 14,293 articles with authors all from Serbia. Distribution of published articles in the Web of Science categories, journals, scientific-research institutions and researchers were analysed. Most cited independent research articles from Serbia were also analysed. The *Y*-index indicator for rating the productivity of researchers and institutions was used. This indicator takes into account the contribution of the researcher to the published results. The results showed that the productivity of articles from Serbia is significant compared to neighbouring Serbian countries, taking into account the number of researchers in these countries, their GDPs and the percentages of GDPs spent on research.

Keywords Serbia · SCI-EXPANDED · Web of Science · Research trends · *Y*-Index

Introduction

The Republic of Serbia became an independent country in 2006. Since then, this small country has gained recognition for its rapidly increasing scientific outputs. Serbia has been awarded the status of *rising star* several times by Thomson Reuters as a country that has achieved the highest increase percentage-wise in total citations for a specific period

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(http://archive.sciencewatch.com/dr/rs/11jul-rs/, http://archive.sciencewatch.com/dr/rs/10jan-rs/, http://archive.sciencewatch.com/dr/rs/09jan-rs/). The University of Belgrade, Serbia's biggest university, was included in the top 500 universities according to the Academic Ranking of World Universities 2012, in the best 400 universities in 2013 and in the best 150 universities according to Academic Ranking of World Universities in Mathematics 2013. 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.

Bibliometric analysis provides an important method for characterising research (Moravcsik 1985; Fu and Ho 2013). Bibliometric analysis can be useful for making decisions regarding the further development of science (Lucio-Arias and Leydesdorff 2009).

Despite bibliometric indicators not being a perfect measure for valuing science, their use is widespread worldwide (Moed 2006; Adams 2009). In recent years, bibliometric analyses have been particularly focused on bibliometric indicators (Wang et al. 2010; Ho 2013). Bibliometric analyses have been used for comparing the scientific production of several countries (Schubert et al. 1989; Glänzel et al. 2002; King 2004; Hu and Rousseau 2009; Ho 2013). Analyses of the scientific production of a single country, such as the Republic of South African (Jeenah and Pouris 2008), China (Fu et al. 2011; Fu and Ho 2013), Brazil (Leta and Chaimovich 2002), Russia (Markusova et al. 2009), The Netherlands (Moed et al. 1995), Morocco (Bouabid and Martin 2009) and Estonia (Allik 2008) have been studied using bibliometric indicators. 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).

The bibliometric analysis presented in this paper is not the first analysis of Serbian scientific publications. In 2009, research regarding the citations of papers written by researchers from Serbia was published (Filipi-Matutinovic et al. 2009). This research was based on the citation of all papers from SCI-EXPANDED and from a Serbian citation base that stores only papers published in journals based in Serbia. The research was limited to papers from 1,487 researchers, which excluded papers from a lot of researchers from Serbia. Additionally, the research was limited to papers published in the period 2003–2008. Moreover, bibliometric analyses of journals based in Serbia were covered in the paper (Popović et al. 2012; Šipka 2012; Jaćimović et al. 2010). Bibliometric analyses of published results from a selection of distinguished researchers from Serbia were presented in the paper (Šipka 2005; Filipi-Matutinović 2007). Bibliometric analysis of publications from Serbia in the field of nanoscience and nanotechnology was covered in the paper (Ševkušić and Uskoković 2009). Published results in the Balkan area, which includes Serbia, were included in the paper (Thomaidis et al. 2004).

There is an entire sequence of research that deals with published results of the Republic of Croatia, which until 1991 had not been independent, but belonged to the former Yugoslavia, which also included the Republic of Serbia up to 1991 (Bencetić Klaić and Klaić 2004; Borić and Strujić 2006; Bencetić Klaić and Klaić 1997; Klaić 1997). Prior to the current paper, a sequence of bibliometric analyses that included papers from Serbia was published, but unlike research shown in this paper, they used a different data set that was smaller than the data set used in this paper. The methodology and bibliometric indicators applied in this research are different from previous studies.

The purpose of this paper is to identify and analyse journal publications contributed independently by Serbia in the Science Citation Index Expanded (SCI-EXPANDED) database from 2006 to 2012. The analysis covers annual production, field performance,

journals, research emphases, contributing institutions and researchers, and most cited articles. Some newly developed indicators related to title words, author keywords, first author and corresponding author were employed to provide additional insights.

Data set, research methodology and limitations

Data set

Data used in this research were taken from Thompson Reuters Web of Science, the online version of the Science Citation Index Expanded (SCI-EXPANDED), on 26 June 2013. A basic search was conducted using the keyword "Serbia" in the field address and the retrieved results were limited to results published during the period 2006–2012. Retrieved results were additionally refined by excluding all other countries that were not the country "Serbia", for example, "USA", "Germany", "Serbia Monteneg", and etc. Articles were the only document type considered. In total, 14,293 Serbian independent published articles were analysed. Document information 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 into Microsoft Excel software.

Research methodology

After downloading data, a consolidation of data concerning contact addresses was performed in order to enable determining the institutions to which authors of articles were affiliated. The following indicators were used during the analysis:

- TP—total number of analysed independent articles from Serbia
  - That were published in a certain year,
  - That belonged to a certain Web of Science category,
  - That were published in a certain journal,
  - Had at least one author affiliated to a certain institution,
- TSCI—total number of articles in SCI-EXPANDED published in the period 2006–2012
  - That were published in a certain year,
  - That belonged to a certain Web of Science category,
  - That were published in a certain journal,
- *TP/TSCI%*—percentage of articles from Serbia in the total number of articles published in SCI-EXPANDED in the period 2006–2012
  - That were published in a certain year,
  - That belonged to a certain Web of Science category,
  - That were published in a certain journal.

The *TP/TSCI%* indicator was previously used in the paper (Kostoff et al. 2008) for comparing the production of the most productive countries during certain years with production of all researchers from all over the world.

In an era of increasing multiple-authorship (National Science Board 2010), the contribution of authors was diluted. However, not only the popular indicators, such as the

number of publications, number of citations, world share of publications (Leydesdorff 2012), citations per publication (CPP) (Moed et al. 1985), *h*-index (Hirsch 2005), *g*-index (Egghe 2006), *A*-index (Jin 2006) and impact factor (Bornmann et al. 2012), but also some newly develop methods such as *R*-index (Jin et al. 2007), *AR*-index (Jin et al. 2007), *h*-type index for journals (Schubert and Glänzel 2007), a dynamic *h*-type index (Rousseau and Ye 2008) and h_α- and g_α-indices (van Eck and Waltman 2008) did not take authorship into consideration. Schubert introduced the partnership ability index (φ), relying on the number of co-authors and the times each of them acted as co-authors with a given author (2012). Fractional counting by first or corresponding authors was useful for the assessment of research productivity and impact (Huang et al. 2011). Principle 5.12-1 of the Ethical Standards of Psychologists of the American Psychological Association (1953) states: "the experimenter or author who has borne the principal responsibility for a piece of research or writing should be identified as the first author, and those who have made less but significant contributions should appear as junior authors".

A corresponding author obviously increases the author's credit for contributions to the study (Bhandari et al. 2004). The designation of corresponding author, also known as responsible author is important, since he/she supervises the planning and execution of the study and the writing of the article (Burman 1982). A newly developed indicator, *Y*-index (Ho 2013), which considers two prominent authorships, i.e., first author and corresponding author, was employed in the current paper. Not only could it reveal the major contributors, ignoring unethical authors such as gift authors, but it also provided deep insight into the features of contribution. The *Y*-index (j, h) indicator rates the productivity of researchers, institution or country by taking into account the contribution of the researcher to the published result (Ho 2013). This indicator has two parameters:

$$j = FP + RP, \tag{1}$$

$$h = \tan^{-1}\left(\frac{RP}{FP}\right), \tag{2}$$

where j is publication performance constant related to publication quantity and h is publication characteristics, which can describe the proportion of FP to RP. The parameter FP used in this formula was the number of articles in which the researcher was the first co-author or the only author; parameter RP was the number of articles where the researcher was the corresponding author or the only author. The value of the parameter $h = 0.7854$ indicated that $FP = RP$, the value of the parameter $h < 0.7854$ indicated that $FP > RP$ and the value of parameter $h > 0.7854$ indicated that $FP < RP$.

For calculating the *Y*-index indicator, we need information about the article's corresponding author. In the Thompson Reuters Web of Science citation base, corresponding author is labelled as "reprint author"; however, the research shown in this paper uses the term "corresponding author" (Ho 2013). 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.

Limitations

There were some limitations to our research as stated in the description of the data set used and the applied methodology. The first research limitation was data source; we analysed publications indexed in the SCI-EXPANDED database, because we believed this database

included enough significant research publications relevant for our research and conclusions. The second research limitation was time frame; we analysed research publications published in the period 2006–2012. The reason for this was the fact that Serbia became an independent country in 2006 and only Journal Citation Reports (JCR) of 2012 was available at the time our research commenced. The third significant limitation was the fact that we analysed only publications in which all authors' contact addresses were located within Serbia. During 2006–2012, there were 174 articles in SCI-EXPANDED that had more than 1,000 authors and included at least one author using address in Serbia. Most of the top cited articles from Serbia did not have its first author or corresponding author articles. The contribution of Serbia was therefore significantly diluted and was not meaningful for the performance of Serbian science. Additionally, the first authors or corresponding authors are usually observed from G7, especially from the USA in terms of international collaboration from one developing country. Various distractions from outside of Serbia could partly be too complicated for discovering true research performance. Independent publications without external factors could provide a new method for analysing Serbian publications in which research and writing were undertaken only by researchers from Serbia. Although some scientific results with major contributions by Serbian researchers were excluded, scientific results with minor contributions by Serbian researchers were also disregarded. Another limitation was selecting only one document type for analysing articles. Articles contain description of complete researches and results (Ho et al. 2010). Also, article document type is the most numerous of the all document types in the SCI-EXPANDED citation database. We used the *Y*-index indicator in our bibliometric analysis. The fact that only articles with both first author and corresponding author information in the Thompson Reuters Web of Science citation base could be considered for calculating the *Y*-index indicator was a limitation of this indicator. In total 14,222 (of 14,293) articles with both first and corresponding authors information were analysed using the *Y*-index. Also, the fact that creation of authorship list are not always based on contribution and can be also based on alphabetical order or reverse seniority can be limitation of using *Y*-index. However, the approach most often used is ordering by contribution, especially for articles with a few authors (Tscharntke et al. 2007).

Results and discussion

A total of 14,293 independent Serbian articles published in the period 2006–2012 in SCI-EXPANDED were found. Ninety-two per cent of all these articles were published in English ($n = 13{,}192$), 5.9 % in Serbian ($n = 843$) and less than two per cent in other languages. There were 6,170 articles (43 % of 14,293 articles) with information about funding in Web of Science. Additionally, 472 various funding programmes were found. In total, 5,475 articles (89 % of 6,170 articles) had only one funding. 6,071 articles (98 % of 6,170) had been supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia, followed at a distance by funding provided by the Provincial Secretariat for Science and Technological Development of Vojvodina (133; 2.2 %), the European Commission (110; 1.8 %) and the Serbian Academy of Sciences and Arts (63; 1.0 %).

The number of articles from Serbia by publication year is discussed, as well as the subjects covered by most researchers from Serbia. Distribution of articles by subject categories and journals are identified and the most frequently used words in titles, author keywords, and abstract of articles are highlighted. The final section of this paper revealed

the institutions, researchers and articles from Serbia with the highest impact on the global scientific community, the distribution of articles by scientific institutions and researchers and the most cited articles from Serbia.

Number of publications

The number of articles from Serbia ($n = 14{,}293$) are compared to its neighbouring countries in Table 1. The total number of independent articles per country was obtained from the SCI-EXPANDED database using the data set selection described in "Data set, research methodology and limitations" section. Other indicators shown in the table were obtained from World Bank Open Data (http://data.worldbank.org). These indicators were related to the year 2009, which is in the middle of the period 2006–2012. Taking into account the number of researchers, GDP per capita and the percentage of GDP spent on R&D, research production in Serbia is good. Croatian research also showed significant productivity, but it should be taken into account that indicator R2009 (number of researchers per million) for Croatia is much higher compared to Serbian R2009, meaning the number of researchers in Croatia is similar to that of Serbia. Additionally, GDP is much higher in Croatia; therefore, Serbian productivity is very good, considering how few resources are made available to Serbian academia. Table 1 also shows the productivity of scientific publications from Serbia and its neighbouring countries, but does not show the impact of scientific publications. In other words, the comparison of Serbia and its neighbouring countries were conducted by quantity, not quality.

The production of Serbian independent articles during the past couple of years has seen a higher increase than the increase of all articles in the SCI-EXPANDED database (Table 2). The number of journals indexed by SCI-EXPANDED has increased every year, from 4,963 journals in 1997, to 8,411 journals in 2012. Hence, the number of articles indexed by SCI-EXPANDED has seen an increase in terms of Serbian independent articles that is considerably greater than the increase in number of all articles in SCI-EXPANDED. As such, the ratio of articles from Serbia in total is becoming larger every year. The reason for this 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 Serbia and Montenegro, which comprised the Republic of Serbia and the Republic of Montenegro. A certain number of articles written by authors affiliated with institutions that are located in

Table 1 Productivity comparison with neighbouring countries

Country	*TP*	*P2009*	*R2009*	*GDP2009*	*R&Dexp2009%*
Romania	23,107	21,480	895	7,651	0.47
Hungary	16,042	10,022	2,006	12,635	1.17
Serbia	14,293	7,320	1,060	5,498	0.92
Croatia	10,466	4,429	1,571	14,054	0.85
Bulgaria	6,462	7,585	1,587	6,403	0.21
Bosnia and Herzegovina	1,005	3,853	–	4,433	0.02
Macedonia	531	2,101	–	4,434	–
Montenegro	185	619	–	6,713	–

TP: number of country independent articles for the period 2006–2012; *P2009*: country total population in 2009—expressed in thousands of citizens; *R2009*: number of researchers per million in 2009; *GDP2009*: country GDP per capita in 2009; *R&Dexp2009%*: percentage of GDP spent on R&D in 2009

Table 2 Number of publications in SCI-EXPANDED

Year	*TP*	*TPG%*	*TSCI*	*TSCIG%*	*TP/TSCI%*
2012	3,347	25	1,163,718	3.7	0.29
2011	2,684	14	1,121,790	6.0	0.24
2010	2,363	11	1,058,169	3.7	0.22
2009	2,120	23	1,020,352	3.6	0.21
2008	1,725	18	985,225	5.9	0.18
2007	1,457	144	930,340	4.4	0.16
2006	597	–	891,088		0.067

TP: independent Serbian articles; *TPG%*: increase in the number of independent Serbian articles in a certain year compared to previous the year, expressed in percentages; *TSCI*: total number of articles in SCI-EXPANDED; *TSCIG%*: increase in the number of articles in SCI-EXPANDED in a certain year compared to the previous year, expressed in percentages; *TP/TSCI%*: percentage of independent Serbian articles in the total number of articles in SCI-EXPANDED

the area which belong to the country today known as the Republic of Serbia applied under the address of former country 'Serbia and Montenegro' were not entered into the statistics for 2006. In 2006, there were 459 articles that were according to their addresses tied to the former Serbia and Montenegro.

The Republic of Serbia has 14 times more residents than the Republic of Montenegro and the number of researchers from the former is also 10 times greater than the number of researchers from the latter. Therefore, most of the 459 articles of the former state Serbia and Montenegro were written by researchers that were employed in scientific institutions that is today the Republic of Serbia. After classifying these 459 articles to Serbia, the increase of articles published in 2007 compared to 2006 was around 40 % instead of 144 % (Table 2). The increase of Serbian articles in the latter period of 2006–2012 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 (http://www.mpn.gov.rs/images/content/nauka/pravna_akta/PRAVILNIK_o_zvanjima.pdf).

The rule book for evaluation of scientific-research results in the Republic of Serbia 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* and *Journal of the Serbian Chemical Society*, all of which are issued by Serbia, published a considerable number of articles whose authors were from Serbia.

Web of Science categories and journals

Table 3 shows the distribution of articles in the top ten Web of Science categories according to the number of Serbian independent articles. A total of 1,633 articles (11 % of all Serbian independent articles; 1.5 % of SCI-EXPANDED articles) were published in the category general and internal medicine. Forty-seven per cent of 1,633 articles in this category were published by the Clinical Centre of Serbia (34 %), the University of Belgrade (29 %), the Military Medical Academy (16 %) and the University of Nis (12 %). Since the population of Serbia only accounts for little more than 0.1 % of the global

Table 3 Top ten productive Web of Science categories

Web of Science category	*TP*	*TP%*	*TSCI*	*TP/TSCI%*
General and internal medicine	1,633	11	109,370	1.5
Multidisciplinary chemistry	762	5.3	267,058	0.29
Applied mathematics	741	5.2	143,840	0.52
Chemical engineering	698	4.9	145,757	0.48
Biology	646	4.5	56,823	1.1
Multidisciplinary materials science	538	3.8	378,870	0.14
Electrical and electronic engineering	532	3.7	276,644	0.19
Mathematics	517	3.6	144,214	0.36
Environmental sciences	442	3.1	191,414	0.23
Physical chemistry	428	3.0	291,715	0.15

TP: independent Serbian articles; *TP%*: percentage of articles in a category to *TP*; *TSCI*: total articles in SCI-EXPANDED; *TP/TSCI%*: percentage of independent Serbian articles in SCI-EXPANDED

population, the productivity of Serbia in general and in the field of internal medicine can be considered outstanding.

Each category shown in Table 3 has a world share greater than 0.1 %. If the list were to be sorted by share, the list shown in Table 3 would be different. Second place would be awarded to the scientific field of biology, with 1.1 % of the global number of articles. Amongst these ten categories, two categories belong to the field of mathematics: applied mathematics and mathematics, and three belong to the field of chemistry: multidisciplinary chemistry, chemical engineering and physical chemistry. There are also categories that overlap with the field of chemistry: multidisciplinary materials science and environmental sciences. 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 2006–2012 and in what field they mostly contributed to in world science might be different. Figure 1 shows publication trends of the top eight categories by year in the period 2006–2012. The category of general and internal medicine recorded a significant growth in number of articles per year in the period 2008–2012, as did the category of electrical and electronic engineering in the period 2009–2012; others categories fluctuated during the period 2007–2012.

A word statistical analysis technique was used to identify the research focus of Serbia. We divided the words in the article title and abstract, as well as those in the author keywords into single words and statistically analysed them. The technique of statistical word analysis in the titles, abstracts and author keywords were aimed at discovering the particular context of the studied science (Xie et al. 2008; Zhang et al. 2010). The most frequently used words in article titles were ordered decreasingly by frequency of occurrence, i.e., *Serbia*, *patients*, *influence*, *properties*, *activity*, *system* and *treatment*. The most frequently used words in abstracts were ordered decreasingly by the frequency of occurrence, i.e., *paper*, *method*, *methods*, *significant*, *aim*, *patients*, *significantly*, *parameters*, *time*, *treatment*, *system*. Furthermore, the most frequently used keywords that authors defined were ordered decreasingly by frequency of occurrence, i.e., *Serbia*, *diagnosis*, *treatment outcome*, *oxidative stress*, *antimicrobial activity* and *risk factors*. Dominant words among those most frequently used in titles, abstracts and keywords were words often used in the scientific field of medicine. Also present were words that are frequently used in

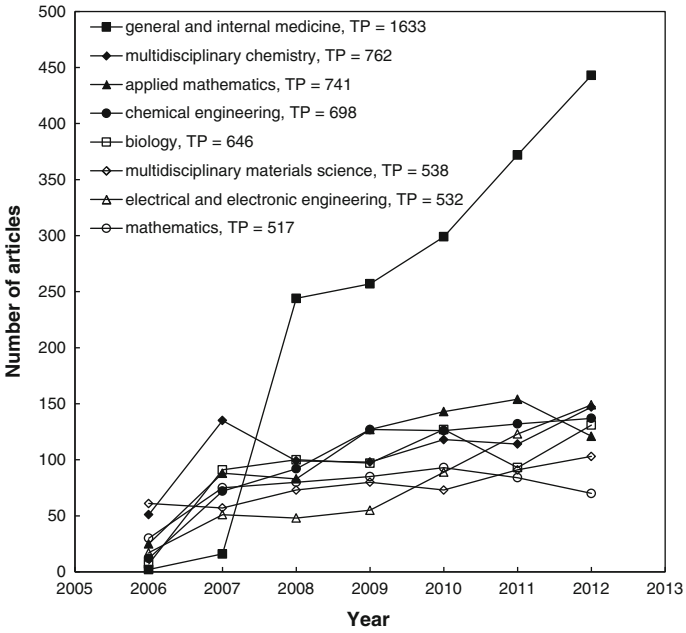

Fig. 1 Top eight Web of Science subject categories by number of independent Serbian articles

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 3.

The value of the indicator *IF2012* for each journal was obtained from JCR for 2012. Table 4 shows the distribution of articles in the top 15 journals, with 100 or more articles from Serbia. Indicators TSCI and *%TP/TSCI* represented the total number of articles in these journals in the period 2006–2012, as well as the share of articles from Serbian researchers in total number of articles published in these journals in the period 2006–2012, respectively. The journal with the most published articles was *Vojnosanitetski Pregled*, which published 705 articles, 4.9 % of all articles in Serbia. *Vojnosanitetski Pregled* falls into the category of general and internal medicine and had a 2012 impact factor of 0.21. In third place was *Srpski Arhiv Za Celokupno Lekarstvo*, which also belonged to the category of general and international medicine and had a 2012 impact factor of 0.228. The category general and internal medicine contained journals with a much higher average 2012 impact factor of 2.55. 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 published articles were written by researchers from Serbia (92 % of articles in *Vojnosanitetski Pregled*; 86 % of articles in *Srpski Arhiv Za Celokupno Lekarstvo*). Most articles in these journals were in English, but there were also articles in Serbian that were undoubtedly less accessible to the global scientific community. These Serbian journals within the category of general and internal medicine were placed amongst the 15 % of journals with the weakest impact on world research community according to the value of *IF2012*. On one side, Serbia—with little more that 0.1 % of the global population—published 1.5 % of all publications in the category of general and international medicine during 2006–2012; on the other hand, over 70 % of these articles from

Table 4 Distribution of publications in SCI-EXPANDED journals

Journal	*TP* (%)	*IF2012*	Web of Science category	*TSCI*	*%TP/TSCI*
Vojnosanitetski Pregled	705 (4.9)	0.210	General and internal medicine	764	92.28
Archives of Biological Sciences	484 (3.4)	0.791	Biology	772	62.69
Srpski Arhiv Za Celokupno Lekarstvo	475 (3.3)	0.228	General and internal medicine	555	85.59
Journal of the Serbian Chemical Society	405 (2.8)	0.912	Multidisciplinary chemistry	980	41.33
Hemijska Industrija	331 (2.3)	0.463	Chemical engineering	411	80.54
Technics Technologies Education Management-TTEM	232 (1.6)	0.414	Multidisciplinary engineering	541	42.88
Healthmed	219 (1.5)	N/A	General and internal medicine	1274	17.19
Acta Veterinaria-Beograd	215 (1.5)	0.258	Veterinary sciences	406	52.96
Thermal Science	164 (1.1)	0.838	Thermodynamics	673	24.37
Metalurgia International	163 (1.1)	0.134	Metallurgy and metallurgical engineering	2575	6.33
Genetika-Belgrade	151 (1.1)	0.372	Agronomy; genetics and heredity	208	72.6
Applied Mathematics and Computation	144 (1.0)	1.349	Applied mathematics	7703	1.87
Journal of Buon	121 (0.85)	0.761	Oncology	570	21.23
Acta Physica Polonica A	106 (0.74)	0.531	Multidisciplinary physics	3298	3.21
Science of Sintering	101 (0.71)	0.278	Ceramics materials science; metallurgy and metallurgical engineering	247	40.89

% the percentage of the number of publications in the journal to the total number of analysed articles; *N/A* not available in 2012

Serbia were published in 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 99.5 % of 1,633 articles published in the category general and internal medicine had less than ten citations and more than 67 % of these articles were without any citations. The most cited article in this category has 17 citations. Therefore, the impact of published articles from Serbia in the category of general and internal medicine did not follow the quantity of published articles in this category.

Six of the top eight journals shown in Table 4 were based in Belgrade, while only *Technics Technologies Education Management-Team* and *Healthmed* were not based in Serbia, its headquarters being in the Serbian neighbouring country of Bosnia and Herzegovina. Some of these top eight journals also had small impact factors and most papers published in these journals were written by Serbian researchers. The journal *Applied Mathematics and Computation* had the highest *IF2012*, which belonged to the scientific category applied mathematics. Recognition of Serbian scientific results in the category of mathematics was noted by the fact that for the first time, the University of Belgrade was ranked within the top 100–150 ARWU in the field of mathematics.

Figure 2 shows distribution of the number of articles from Serbia by year in the top eight SCI-EXPANDED journals shown in Table 4. It is obvious that SCI-EXPANDED began to index the journals *Vojnosanitetski Pregled* and *Srpski Arhiv za Celokupno Lekarstvo* in 2008. A dramatic increase in terms of number of articles concerning these two

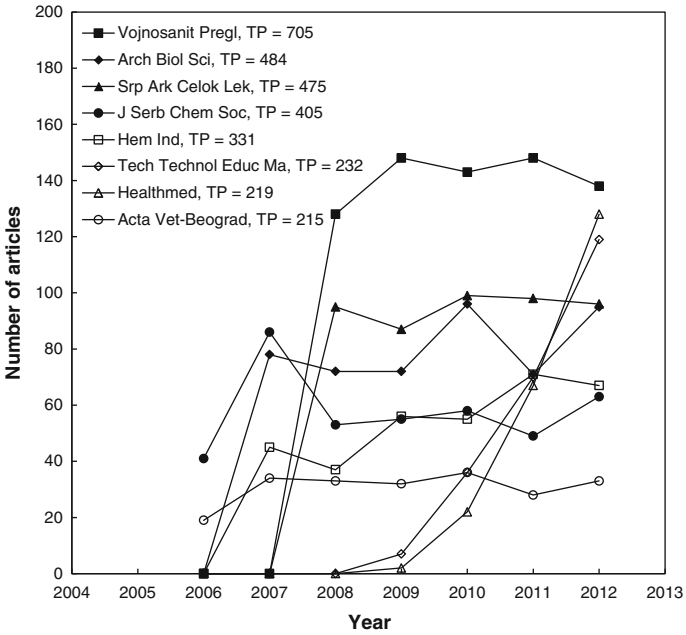

Fig. 2 Top eight journals by number of independent Serbian articles

Table 5 Distribution of publications per scientific institution

Institution	*TP*	*TP R* (%)	*IP R* (%)	*CP R* (%)	*FP R* (%)	*RP R* (%)	*SP R* (%)	*R* (*j*)	*h*	*S*%
University of Belgrade	8,033	1 (56)	1 (53)	1 (61)	1 (43)	1 (43)	1 (39)	1 (12,385)	0.7847	55
University of Novi Sad	2,274	2 (16)	2 (14)	2 (19)	2 (12)	2 (12)	3 (12)	2 (3,303)	0.7845	50
University of Nis	1,697	3 (12)	3 (10)	4 (14)	3 (8.9)	3 (8.9)	4 (10)	3 (2,538)	0.7846	50
Clinical Centre of Serbia	1,356	4 (9.5)	5 (3.5)	3 (18)	5 (5.1)	5 (5.0)	6 (1.5)	5 (1,440)	0.7757	22
University of Kragujevac	1,204	5 (8.4)	4 (5.3)	5 (13)	4 (5.7)	4 (5.7)	5 (4.7)	4 (1,624)	0.7854	37
Serbian Academy of Sciences and Arts	693	6 (4.8)	6 (2.9)	6 (7.7)	6 (2.8)	6 (2.8)	2 (16)	6 (807)	0.7916	35
Military Medical Academy	577	7 (4.0)	7 (1.6)	7 (7.6)	7 (2.0)	7 (2.0)	9 (0.67)	7 (570)	0.7819	23
University of Prishtina	326	8 (2.3)	9 (0.62)	8 (4.6)	9 (1.0)	9 (1.0)	8 (1.2)	9 (279)	0.7746	16
Clinical Centre of Vojvodina	254	9 (1.8)	8 (0.87)	10 (3.1)	8 (1.1)	8 (1.0)	21 (0.25)	8 (295)	0.7752	29
Institute for Oncology & Radiology of Serbia	231	10 (1.6)	11 (0.48)	9 (3.2)	10 (0.77)	10 (0.75)	21 (0.25)	10 (217)	0.7716	17
Institute of Field and Vegetable Crops	168	11 (1.2)	10 (0.52)	13 (2.1)	11 (0.62)	11 (0.62)	34 (0.083)	11 (176)	0.7968	26
University Childrens Hospital	156	12 (1.1)	13 (0.33)	11 (2.2)	13 (0.56)	13 (0.55)	15 (0.33)	13 (158)	0.7854	18
Institute for medical plants research Dr. Josif Pancic	132	13 (0.92)	41 (0.048)	11 (2.2)	22 (0.27)	22 (0.27)	N/A	22 (76)	0.7854	3.0
Clinical Centre in Nis	125	14 (0.87)	27 (0.11)	14 (2.0)	21 (0.31)	21 (0.32)	34 (0.083)	21 (91)	0.7964	7.2
Maize Research Institute	119	15 (0.83)	12 (0.41)	17 (1.4)	12 (0.57)	12 (0.57)	N/A	12 (162)	0.7854	29
Oncology Institute of Vojvodina	119	15 (0.83)	24 (0.13)	15 (1.8)	19 (0.34)	19 (0.34)	N/A	19 (96)	0.7854	9.2
Institute for Technology of Nuclear and Other Raw Materials	101	17 (0.71)	20 (0.2)	18 (1.4)	14 (0.42)	14 (0.42)	34 (0.083)	14 (120)	0.7854	17

TP: total independent Serbian articles; *IP*: institutional independent articles; *CP*: inter-institutionally collaborative articles; *FP*: first author articles; *RP*: corresponding author articles; *SP*: single author articles; *j* and *h*: constants of *Y*-index; *S*%: percentage of institution independent articles; *R*: rank; *N/A*: not available

journals, belonging to the category of general and internal medicine between 2007 and 2008 (Fig. 1) were observed, which is consistent with the entry of these two journals on the list of journals. Similarly, it can be concluded that the entry of journals, which are based in Serbia on the list of journals and are indexed by SCI-EXPANDED, had an impact on the growth of articles from Serbia being published. Figure 2 shows a sudden increase in the number of research articles from Serbia in the journals *Technics Technologies Education Management—TTEM* and *HealthMed* during the period 2009–2012.

Scientific institutions, researchers and most cited articles

Collaboration type was determined from the addresses of the authors. The articles were classified into six types based on the institution (Ho 2014): (1) *TP*: the number of total articles of an institution; (2) *IP*: the number of single institution articles, if the researchers' addresses were from the same institution; (3) *CP*: the number of inter-institutionally collaborative articles, if authors were from different institutions; (4) *FP*: the number of first author articles, if the first author was from the institution for analysis; (5) *RP*: the number of corresponding author articles, if the corresponding author was from the institution for analysis; (6) *SP*: the number of single author articles, if the author was the only one in an article. Table 5 shows the distribution of publications from Serbia by scientific institutions. The meaning of used indicators in Table 5 is explained below the table. Columns where the header contains *R* (%) following the abbreviation for an indicator do not show the values of that indicator. The value in brackets shows the percentage of the number of articles for which the institution was responsible in the total number of articles from all Serbian institutions that are taken into account. The value before the brackets shows positions of the certain institution in the list of Serbian institutions ordered by the certain indicator. For example, the value of the first line in column *IP R* (%) is 1 (53), which means that the University of Belgrade took first place according to the number of articles in which all authors were affiliated at that institution; this university published 53 % of all articles in which all authors were affiliated with the same institution.

Column *R* (*j*) shows the position of the institution by value of the *Y*-index parameter *j*, which is listed within brackets. The percentage of institution independent articles is listed in the final column. According to the values of the indicators shown in Table 5, first place is awarded to the University of Belgrade, which is the largest science-education institution in Serbia. This university is located in Belgrade, the capital of Serbia and the only city with over one million residents. This university has 31 faculties, 11 scientific institutes and over 10,000 employed researchers (http://www.scopus.com/affil/profile.url?afid=60068815). During the period 2006–2012, this university published 56 % of the articles analysed. Moreover, this university was included in 2012 in the top 500 universities as listed on the Academic Ranking of World Universities 2012 (http://www.shanghairanking.com/ARWU2012.html). Furthermore, the university was included in the top 400 universities according to Academic Ranking of World Universities 2013 (http://www.shanghairanking.com/ARWU2013.html) and in the best 150 universities according to the Academic Ranking of World Universities in Mathematics 2013 (http://www.shanghairanking.com/SubjectMathematics2013.html). In addition to others indicators, Academic Rankings of World Universities take into account the number of published results in the Thomson Reuters Web of Science citation base, which includes papers published in conference proceedings, as well as journals articles (including Serbian independent articles published in the SCI-EXPANDED database analysed in this paper). Furthermore, the size of the institution is also important, as one indicator denotes the per capita academic performance

of an institution (PCP). The University of Belgrade took first place by all remaining indicators shown in the Table 5: number of articles whose authors are affiliated with the same institution, number of articles that are the result of cooperation between authors from different institutions in Serbia, number of articles where the first author was from a certain institution, number of articles where the corresponding author was from a certain institution, as well as the number of single author articles. The value of the j parameter for the University of Belgrade was 12,385, which is considerably larger than the values for all other institutions. An institution with a higher j indicates more articles in the category first or corresponding author. The second and third place were taken by the University of Novi Sad (with over 2,500 researchers—http://www.scopus.com/affil/profile.url?afid=60068801) and the University of Nis (with over 1,700 researchers—http://www.scopus.com/affil/profile.url?afid=60068806), respectively. These two universities took second and third place, with the exception being the category number of articles that were the result of cooperation between authors affiliated with different institutions in Serbia and in the category number of single author articles. According to the number of articles that were the result of cooperation between authors affiliated with different institutions, third place belonged to the Clinical Centre 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 Clinical Centre of Serbia had been written in cooperation with researchers from the University of Belgrade. In a certain number of articles by researchers from the Clinical Centre of Serbia, a corresponding author was from the Medical Faculty of the University of Belgrade; this is why Clinical Centre of Serbia's h parameter is slightly lower than 0.7854. With respect to the number of single author articles, second place was awarded to the Serbian Academy of Science and Arts. There are many institutions that deal with medical research, which is in accordance with the fact that most published articles from Serbia belonged to the scientific field of general and internal medicine (Table 4).

Figure 3 shows researchers from Serbia with the highest j parameter value in the Y-index, where the j Cos h and j Sin h were chosen as the x and y coordinate axes. The value of the j parameter will be significantly different for researchers that have had intensive cooperation with researchers from other countries if analysis included articles where authors from Serbia were co-authors with researchers from abroad. Distance of point from coordinate beginning is directly proportional to the value of the Y-index j parameter of a certain researcher. If the point of the researcher is above (below) the line $y = x$, the value of Y-index h parameter is greater (smaller) than 0.7854 meaning number of the first author articles is lower (higher) than number of corresponding author articles. By far the greatest value of the j parameter (261) has Stević, S. from the University of Belgrade, which is shown in Fig. 3 as P.S. Stevic, S. (261; 0.7969). Gutman, I., employed at the University of Kragujevac, takes the second place, with $j = 95$. Both of these researchers had more articles in which they were corresponding authors, than articles for which they were first authors. Furthermore, points for 13 researchers with a value of $j \geq 50$ are shown. Eight of the top 13 researchers were above the line $y = x$, which means that eight researchers had a higher proportion of corresponding author articles to first author articles. Figure 3 clearly shows that two authors, Milosevic, T. ($j = 58$) and Cvijovic, D. ($j = 50$) had the same values of h, just on the boundary of the 0.7854 line, thereby having the same quantity of corresponding author articles and first author articles. Milosevic, with a greater value of j, published a larger quantity of first or corresponding author articles than researcher Cvijovic, since j is a constant related to publication characteristics. Simic, S. ($h = 0.7690$)

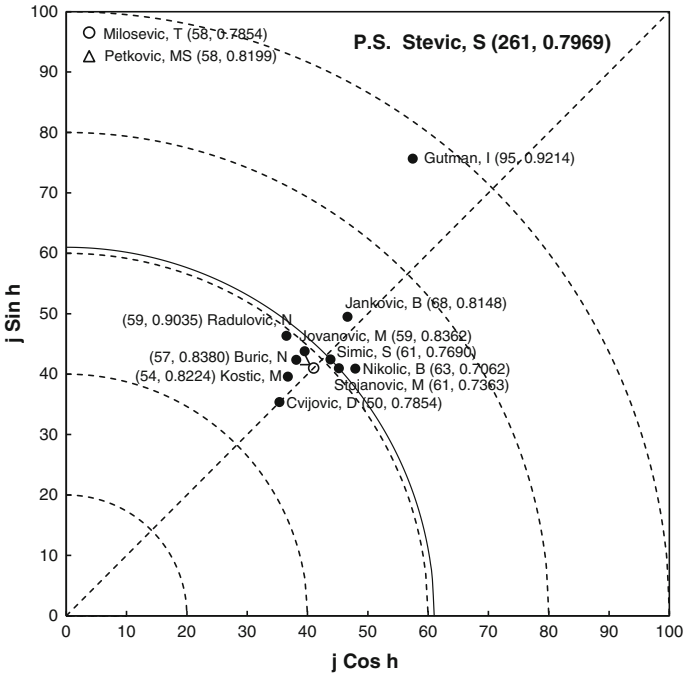

Fig. 3 *Y*-index of the top 13 researchers with the greatest j ($j \geq 50$)

and Stojanovic, M. ($h = 0.7363$) had the same values of j (61), exhibited by the solid line of an arc in Fig. 3, where each dot of the line has the same distance to the original point.

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). It was presented that the corresponding author usually contributed more to the initial conception and supervision, while the first author contributed more to the work performed (Wren et al. 2007). This means that Simic was more likely to be credited for initial conception and supervision, while Stojanovic probably deserved more credit for the work performed. Similar situations can be also found for Petkovic, M.S. (58, 0.8199) and Milosevic, T. (58, 0.7854), as well as Radulovic, N. (59, 0.9035) and Jankovic, B. (59, 0.8362), who had the same value of j, respectively. However, a potential bias will appear in the analysis of authorship of authors who had the same personal name and those who used different names in their publications (for instance, authors who changed the last name). Another potential confounder arises when an author moves from one affiliation to another. It has been strongly recommended that "international identity numbers" be defined for all authors before they published their first paper in a Web of Science-listed journal (Chiu and Ho 2007).

Table 6 shows articles from Serbia in the period 2006–2012 that, up to the end of 2012, had been cited 65 times or more ($TC2012 \geq 65$). 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). Apart from the value of indicators *TC2012*, *C2012*, *C0* and *TC/Y* (listed in brackets), Table 6 also shows the positions that listed articles take according to the value of these

Table 6 Most cited articles

Title	References	Rank (*TC2012*)	Rank (*C2012*)	Rank (*C0*)	Rank (*TC/Y*)
Homotopy-perturbation method for pure nonlinear differential equation	Cvetićanin (2006)	1 (131)	38 (13)	1585 (0)	2 (19)
Biodiesel production from tobacco (*Nicotiana tabacum* L.) seed oil with a high content of free fatty acids	Veljković et al. (2006)	2 (100)	3 (28)	1585 (0)	9 (14)
Common fixed points for maps on cone metric space	Ilić and Rakočević (2008)	3 (96)	15 (19)	412 (1)	2 (19)
Norm of weighted composition operators from Bloch space to *H*-mu (infinity) on the unit ball	Stevic (2008)	4 (90)	168 (7)	10 (9)	4 (18)
Removal of Co^{2+} from aqueous solutions by hydroxyapatite	Smičiklas et al. (2006)	5 (88)	8 (23)	1585 (0)	15 (13)
Antimicrobial and antioxidant properties of rosemary and sage (*Rosmarinus officinalis* L. and *Salvia officinalis* L., lamiaceae) essential oils	Božin et al. (2007)	6 (85)	11 (21)	1585 (0)	9 (14)
Existence of nontrivial solutions of a rational difference equation	Stević (2007)	7 (75)	4 (26)	28 (5)	15 (13)
On a new integral-type operator from the Bloch space to Bloch-type spaces on the unit ball	Stević (2009)	8 (71)	25 (16)	2 (13)	4 (18)
Composition operators between *H*-infinity and *a*-Bloch spaces on the polydisc	Stević (2006)	9 (70)	499 (4)	1585 (0)	29 (10)
Adsorption of heavy metals from electroplating wastewater by wood sawdust	Šćiban et al. (2007)	10 (65)	32 (14)	48 (4)	23 (11)

TC2012: total citations from its publication to the end of 2012; *C2012*: total citations in 2012; *C0*: total citations in publication year; *TC/Y*: *TC2012* per year

indicators. The first article shown in Table 6 was awarded by the Consortium of Libraries in Serbia in the category single author article amongst researchers from Serbia most cited in SCI-EXPANDED. This paper was among 1 % the most cited SCI-EXPANDED articles published in 2006 in the field of physics. The author of this paper, Cvetićanin, L., is employed at the University of Novi Sad and has more than 50 single author articles that are in total cited over 500 times in SCI-EXPANDED. Stević, S. was the researcher with the most articles on this list. This author, as can be seen in Fig. 3, was the researcher with the highest *j* parameter value in the *Y*-index indicator. Insight into the list of articles by this researcher shows that most of his articles have been single author articles. The article of authors Veljković et al. had the highest value of *C2012* of all articles shown in Table 6.

The *C0* indicator, which represents the number of citations in an article's publication year, was highest for articles by the researcher Stević, S. This researcher was very productive and his scientific results were often cited (including hetero citations and self-citations). The *C0* indicator equally takes into account hetero citations and self-citations, although the influence of some articles on the global science community is proportional to the number of hetero citations. Articles with the highest value of *TC*/*Y* indicator were the first and third in Table 6, respectively.

Conclusions

By focusing on Serbian independent articles, this research measured the productivity and influence of Serbian researchers on the global science community without considering the external roles of international collaboration for the period 2006–2012. Firstly, the Republic of Serbia recorded a significant increase in the number of articles during the past few years. Serbia played a more active role in publishing scientific articles in comparison to its neighbouring countries. This initial impressive growth of scientific productivity might be explained by Serbia's name change at the outset of the study period, while the latter growth had been promoted by the introduction of a new rule book in 2008 for the evaluation of scientific-research results, the basis of which is used for the promotion of scientific and teaching positions, as well as the selection of applied projects funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia. This rule book requires Serbian researchers to publish articles in journals that are indexed by SCI-EXPANDED; as a result, the dramatic increase of Serbia's scientific outputs was observed in our study. Secondly, increasing the number of publications from Serbia has also been responsible for the fact that several new journals based in Serbia started to be indexed in SCI-EXPANDED and these journals published a considerable number of articles from Serbia. The most productive journal is *Vojnosanitetski Pregled*, which is located in Serbia and that has been indexed in SCI-EXPANDED since 2008. Pronounced activities of Serbian researchers in the field of general and internal medicine was observed. This scientific field also includes the previously mentioned journal *Vojnosanitetski Pregled*, which had a considerable influence on Serbia becoming one of the most productive countries in the field of general and internal medicine. However, there are some facts that raise questions about the impact of articles published in this journal on the global research community and thus the impact of Serbian researchers on the global research community in the field of general and internal medicine. Furthermore, the University of Belgrade dominated in scientific articles publication in Serbia, which is not surprising, as it is the biggest institution deploying the greatest number of employed researchers in Serbia. With regard to top publication authors, Stevic, S. at the University of Belgrade is the leader according to

the number of first author articles and corresponding author articles, followed by Gutman, I. at University of Kragujevac. There are not many articles from Serbia that has had a significant impact on the global research community, based on citation metrics. However, citation metrics are time-dependant and the upcoming years will show whether introducing a new rule book in 2008 for the evaluation of scientific-research results, besides increased productivity, also brought publishing Serbian articles with high influence to the world scientific community.

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