Qualitative and Quantitative Methods in Libraries (QQML) 4: 259-– 271, 2015

Characteristics of scientific production in Croatia from 1997 to 2014

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Abstract: Common practice today is to evaluate scientific production and influence of scientists through the Journal Impact Factor and citations of scientific papers. In this way, the Science Citation Index (SCI) and Current Contents (CC) have also become the main criterion for evaluating national scientific production. The consequence of this approach is that we have no insight into the overall scientific production in certain countries or certain scientific fields. The aim of this work was to give review of the overall scientific production in Croatia.
Analysis of productions of Croatian scientists was done on the corpus to 413,855 bibliographic units registered in the Croatian scientific bibliography database (CROSBI) in the period from 1997 to 2014. The Croatian scientific bibliography database (CROSBI) provides the most comprehensive presentation of scientific production in Croatia, and analyzes the productivity of the scientific community, by scientific fields and duration of research projects. Also, with an analysis of the dominant types of scientific papers in various scientific fields (book, journal, book chapter, proceedings, etc.). In contrast to the evaluation of science and scientists by citation database and Impact Factor, complete analysis of scientific production provides a presentation of the whole scientific activity and responsibilities of scientists and university academics, whose task is to be mentors to doctoral candidates and young researchers who are typically involved in research projects, as well as writing textbooks, reviews etc. The understanding of the scientific production of any scientific community requires new methods for evaluation of scientific efficiency. Most commonly used as an indicator, Impact Factor allows only fragmentary approach and usually only evaluation of the international impact of certain scientists and journals.
Keywords: scientific community, scientific production, Croatia, CROSBI database, evaluation, social sciences, humanities

Received: 21.3.2015 / Accepted: 1.5.2015 ISSN 2241-1925

1. Introduction

The main issue that preoccupies scientific policy of universities and governments is how to evaluate scientific production. The scientific production can be evaluated from more aspects. At one end of the range of these positions are advocates who depart from the view that scientific production should be evaluated solely through the database such as is offered by Thomson Reuters. At the other end are the advocates who claim that it can be evaluated only from the standpoint of the contribution of science to economic and social development.

Any approach of the evaluation of science has to start from factography, and that means that we need to have data about the number of scientists, projects on which they work and scientific production.

In this paper is, for the first time, presented an overview of the key data for all scientific fields in Croatia, that is for scientific work that is financed from the Ministry of Science, Education and Sports (MSES) published in Croatian scientific bibliography database (CROSBI). The analysis was conducted on a corpus of 413,855 bibliographic data collected from CROSBI, which stores data about scientific papers published by Croatian scientist in the period from 1997 to 2014.

Previous studies of scientific production are made on the fragmented corpus (Đ. Pečarić, 2011) or the partial data (M. Jokić et al., 2012).

Basic starting point of evaluation of social, human and applied sciences by bibliometrics methods are types of scientific papers that are being evaluated. The focus on evaluating only journal papers can lead to the problem that only a certain percentage of the overall work of scientists in those scientific disciplines will be evaluated, as it was already pointed out by research done in other countries (L. Butler, 2006, 2008). Therefore, we are also particularly interested in what type of communication channel different scientific fields prefer.

2. Methods and problems

The analysis of production of Croatian scientists was done on corpus of 413,855 bibliographic data collected from CROSBI. Although the main goal of this database at the time of establishment was to collect the data on scientific output of the research projects financed by MSES, 112,244 bibliographic units cannot be linked to a specific project. There may be several reasons why some publications are not related to projects. It is possible that certain scientists entered all of their publications in the database regardless of funding sources. On the other hand, the base is not adjusted to track changes in funding projects, which happened in the researched period, so papers cannot be linked to the projects on which they were made.

Despite all the limitations that this base has (including incorrectly entered data), it still provides the most comprehensive review of the work of scientists in Croatia. It also includes an indication of other scientific obligations such as: mentoring the dissertations and master's thesis, writing books and scripts and so on.

For the purposes of this analysis, bibliographic data from CROSBI database are associated with the data from the database *zProjekti* that contains information about projects financed by MSES. Analyses by scientific field and time periods are based on data about the duration of the project.

Number of papers published by projects is not sufficient for understanding the scientific production because it is necessary to include the number of scientists who were engaged in projects and in scientific fields in analyzed periods.

3. Productivity of the scientific community

As the San Francisco Declaration on Research Assessment (2012) says "The outputs from scientific research are many and varied, including: research articles reporting new knowledge, data, reagents, and software; intellectual property; and highly trained young scientists", and therefore for the purposes of this paper all kinds of scientific work that are monitored by CROSBI databases, from papers in the journal to patents and dissertations within the projects, are elaborated.

From a total of 354,456 publications that are published within the projects, the distribution of bibliographic records according to scientific fields are the following: technical sciences 22.4% (79,408), biomedicine and health 19.1% (67,824), natural sciences 18% (63,837), humanities 15.8% (55,948), social sciences, 15.6% (55,219), biotechnical sciences 9.1% (32,220). Distribution of publications by scientific fields mostly follows the number of projects financed in these periods: biomedicine and health care had 1,286 (30.8%) projects, technical sciences 1,045 (25%), natural sciences 941 (22.5%), social sciences 821 (19.6%), humanities 792 (18.9%), and biotechnical sciences had 581 (13.9%) projects.

One of the important features of the evaluation of scientific production is also the understanding of the most appropriate communication channels. Scientific communication channel commonly used by scientists in Croatia (all papers) are papers in proceedings (38%), followed by papers in the journal (32%), chapters in book 7%, books 3%, textbooks 1%, patents 0.1%. The overall production of scientists in this database includes papers in the publishing process, which is 0.7% (that are excluded from further analysis), also the dissertation as an important result of work on the research project 14%, and other scientific forms that do not fall into any of these categories 6%.

According to scientific fields journal as a primary form of communication is dominant in natural sciences (39.4%) and humanities (36.0%); proceedings as the dominant communication channel in: technical sciences (46.0%), biomedicine and health (44.6%), biotechnical sciences (37.6%) and social sciences (34.4%).
The book as a communication channel is most common in humanities 6.6%, then in social sciences 4.4%, in technical sciences 1.5%, in natural sciences 1%, and in biotechnological sciences and biomedicine and health 0.8%.
Chapter in a book as a communication channel is used in humanities 16.8%, in social sciences 11%, in biomedicine and health care 5.9%, in natural sciences 3.6%, in technical sciences 2.5%, and in biotechnology 2.2%.
Scientific and educational responsibilities of scholars can be seen from the data on the number of textbooks, as well as the amount of doctoral dissertations. The range of volumes of published textbooks is from 0.7 to 1.1. The percentage of doctoral dissertations that have been done within projects in different scientific fields range from 4.2% to 27.3%. The largest number of dissertations done on projects is in technical sciences 16,032, which makes 23% of all published works in technical sciences. In natural sciences the number of dissertations done within a project is 7,125, which makes 13% of all bibliographic units in this field. In social sciences 6,117 dissertations were done, which makes 12% of the work, while on projects in humanities 2,381 dissertations were done, which is only 4% of bibliographic units. In biotechnological sciences 5,389 dissertations were done, which is as much as 27% of the total number of bibliographic units done in projects in this field, in contrast to biomedicine and health where a slightly smaller number of dissertations, 4,673, was done, which is only 9% of all papers published in this field.

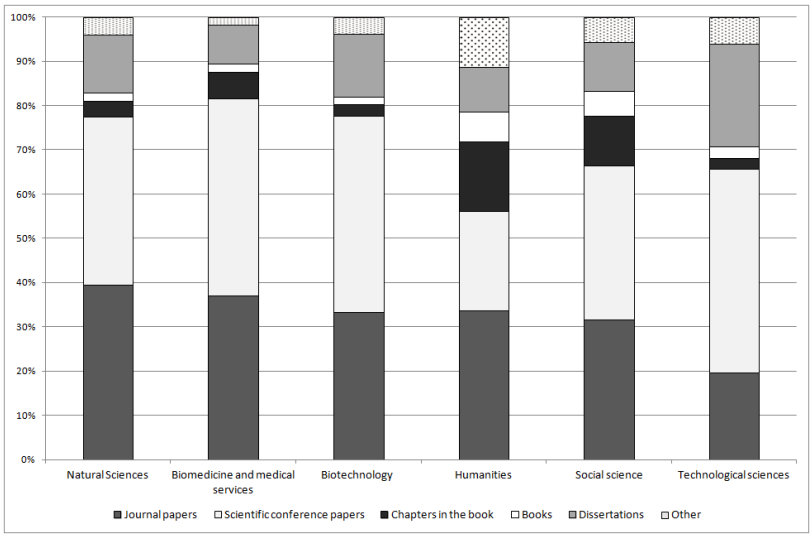


Table 1. Scientific production according to type of publications

Overview of productions of Croatian scientists according to communication channels is presented in Table 1, with certain adjustments that contribute to a greater visibility of data. In that manner, several categories from CROSBI database are joined in one: category 'books' contains authored books and textbooks; and since patents make only 0.2% from overall production, they are placed into the category 'others'.

3.1 Distribution of publications according to time periods

Since the number of published papers is generally correlated with the number of funded projects we were interested if there is a difference in production during different time periods with regard to the number of scientists involved in the projects.

Production of scientists in Croatia is shown (Table 2) according to time periods of duration of the approved projects: 1996-2002, 2002-2006, 2006-2011, and 2011-2014.

In the first period (1996-2002) 67,706 papers were published. In this period 1,300 research projects were financed, which makes an average of 52 papers per project. In the second period (2002-2006) were published 94,016 scientific papers were financed, which makes an average of 50 papers per project.

Table 2. Scientific production according to time periods (of projects)

Projects' time periods	Number of scientific papers	Number of projects
1996 - 2002	67706	1300
2002 - 2006	94016	1849
2006 - 2011	13427	364
2011 - 2014	179307	1953

The lowest number of papers, 13,427, is in the period from 2006 to 2011 (five times smaller than in the first period from 1996 to 2002), but in this period only 364 projects were approved (3.5 times less than the number of projects in the period from 1996 to 2002), which makes an average of 37 papers per project.

The largest number of scientific papers, 179,307, was published in the period 2011-2014. However, this growth is conditioned by the number of projects and the number of scientists engaged in this period. In this period the largest number of scientific projects (1,953) have been granted. This resulted with an average of 92 papers per project.

Another reason for higher production in the period (2011-2014) may lie in the fact that during the earlier period (2006-2011) a small number of 364 projects was granted, but scientists that were not involved in projects continued their work and the accumulation of their independent activities is reflected in the last period. Also the fourth period has an increased number of young researchers involved in research projects and more dissertations were made in this period than in other three previous periods. Increased number of young scientists had as a consequence changed dynamics of productivity of the scientific community.

3.2 Size of the scientific community

Analysis of distribution of publications according to time periods showed that number of papers correlated with number of approved projects for first three periods (1996-2011), with exception of last period (2011-2014) where it has almost equal number of projects as second period (2002-2006) but double number of publication. Since one of the reasons for this higher production in this period may be the number of scientists engaged in this period, we analyses size of the scientific community according to scientific fields and time periods. Size of scientific community presented on table 3 (and in this chapter) is consisted not only from Croatian scientist and scholars but also from authors and co-authors from abroad.

The total number of scientists on projects and their associates in the technical sciences (in the period 1997-2014) was 41,347, in biomedicine and health was 33,755, in natural sciences was 27,479, in social sciences was 15,015, in biotechnical sciences was 13,633, and in humanities 7,316. However, in certain time periods in which projects were funded the numbers of scientists who have collaborated on projects changed (Table 3).

In technical sciences in the first analyzed period, the number of authors was 10,012, in the second period it was 1.2 times higher (13,008), in the third period, when the number of projects was drastically reduced, it was 4,083, and in the last period the number of authors was 1,2 times higher than 10 years earlier. However, the productivity of researchers in technical sciences regardless of the size of the scientific community ranged from 1.2 to 1.7 with the exception of the period from 2006 to 2011 when the projects are kept to a minimum.

In biomedicine and health the number of associates on projects in the first period was 7,323, in the second period it also has increased by 1.7 times and in the last period it has increased three times (23,245), with the exception of the period from 2006 to 2011 when the projects were kept to a minimum. The ratio of the number of scientists on the project and the number of papers in the observed periods is almost equal from 0.8 to 1.6. The average number of published papers on projects in relation to the number of authors is constant except for the third period.

In natural sciences the number of associates on projects in the first period was 8,574, in the second period it has increased by 1.3 times and in the last period it has increased two times (17,534), with the exception of the period from 2006 to 2011 when the projects were kept to a minimum. The ratio of the number of scientists on the project and the number of papers in the observed periods is almost equal from 0.9 to 1.6. The average number of published papers on projects in relation to the number of authors is constant except for the third period.

In social sciences in the first analyzed period, the number of authors was 2,574, in the second period it was 1.6 times higher (4,283), in the third period, when the number of projects was drastically reduced, it was 1,111, and in the last period the number of authors was four times higher than just 10 years earlier. However, the productivity of researchers in social sciences regardless of the size of the scientific community ranged from 2.7 to 3.7 with the exception of the period from 2006 to 2011 when the projects are kept to a minimum.

In biotechnical sciences the number of associates on projects in the first period was 2,891, in the second period it has increased by 1.3 times and in the last period it has increased three times (9,216), with the exception of the period from 2006 to 2011 when the projects were kept to a minimum. The ratio of the number of scientists on the project and the number of papers in the observed periods is almost equal from 0.9 to 2.0. The average number of published papers on projects in relation to the number of authors is constant except for the third period.

Table 3. Size of scientific community and number of publications according to projects' time periods

Number of authors and publications						
Scientific fields		*Periods*				**Total**
		1997-2002	*2002-2006*	*2006-2011*	*2006-2011*	
Social Sciences	No. of authors	2574	4283	1111	11102	**15015**
	No.of publications	9641	13319	1967	30292	**55219**
Humanities	No.of authors	1547	2763	420	5143	**7316**

	No.of publications	9293	15393	1898	29364	**55948**
Biomedicine and health	No.of authors	7323	12635	2960	23245	**33755**
	No.of publications	11176	19783	2280	34585	**67824**
Biotechnical sciences	No.of authors	2891	3867	1102	9216	**13633**
	No.of publications	5673	7166	1028	18353	**32220**
Natural sciences	No.of authors	8574	11629	1401	17537	**27479**
	No.of publications	15254	18349	1296	28938	**63837**
Technical sciences	No.of authors	10012	13008	4083	26263	**41347**
	No.of publications	16669	20006	4958	37775	**79408**

In humanities the number of associates on projects in the first period was 1,547, in the second period it has increased by 1.7 times and in the last period it has increased three times (5,143). The ratio of the number of scientists on the project and the number of papers in the observed periods is almost equal from 5.7 to 6.0 with the exception of the period from 2006 to 2011 when the projects were kept to a minimum. The average number of published papers on projects in relation to the number of authors is constant except for the third period (Table 3).

According to Table 3, we can conclude that the total number of published papers for all analyzed periods, in most dramatic example, in social sciences and humanities is approximately equal (55,219 versus 55,948), although the number of researchers in social sciences was almost two times higher (15,531 compared to 7,584). The differences in these data indicate the need for a detailed analysis of the role of the organization of scientific production in certain fields and

understanding of the nature of multiple authorship and possibilities of collaboration in various scientific fields. We are aware that it is not justified to compare the productivity of scientists in these scientific fields out of these data, although multiple authorship that dominates in social sciences can be equated with the productivity of the authors in the humanities.

3.3 Multiple authorship

The question is why the range of production in biomedicine and health (0.8 to 1.6 papers per author) and natural sciences (0.9 to 1.8 works) in relation to social sciences (2.7 to 3.7 papers) is almost double? And why the range of production in social sciences (2.7 to 3.7 works) in relation to humanities (5.7 to 6.0 papers) is almost double (table 3)? One possible reason is that the scientists in biomedicine and health, natural sciences and social sciences are more prone to collaboration and publishing papers with multiple authors, while in humanities they are more prone to publish papers with single author. To be able to determine how multiple authors affect the overall presentation of the scientific productivity of authors, we analyzed multiple authorship.

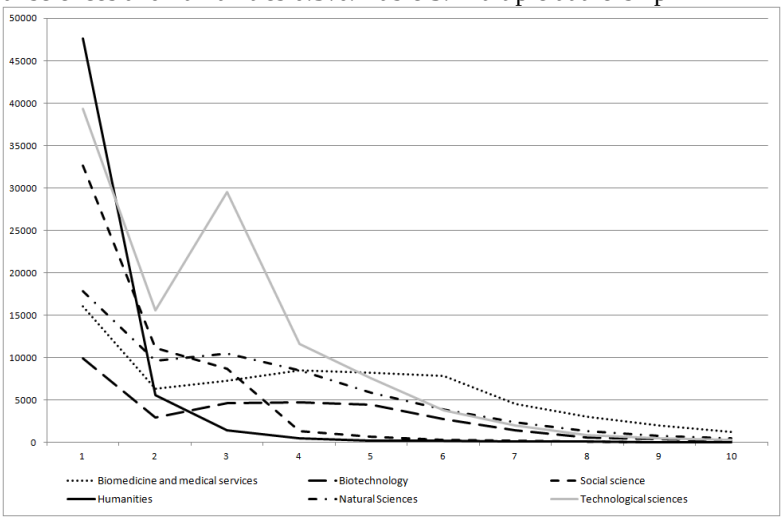
The display of scientific productivity of authors for all fields is following: 42.3% of papers are signed by one author, then 13.2% of the papers are signed by two authors and 16.1% of papers are signed by three authors. However, 9.1% of papers are signed by four authors, and 7% works have even five authors. As much as 16.1% of papers are signed by 6-10 authors, and 1.6% of papers are signed by 11-50 authors. In other words 42.3% of papers are the result of independent work, in collaboration with two or three authors 29.3% of papers are published, in collaboration of 4-10 authors 26.8% of papers are published, in cooperation of 11-50 authors 1.6% of papers are published (Table 4).

Table 4. The number of papers according to the number of authors in different scientific disciplines

No. of authors	Biomedicine and Health	Biotechnical Sciences	Social Sciences	Humanities	Natural Sciences	Technical Sciences	**Total**
1	16085	9894	32626	47590	17844	39324	**163363**
2	6328	2929	11151	5552	9641	15581	**51182**
3	7255	4645	8658	1471	10506	29544	**62079**

No. of authors	Biomedicine and Health	Biotechnical Sciences	Social Sciences	Humanities	Natural Sciences	Technical Sciences	**Total**
4-5	16724	9189	1954	716	14443	19161	**62187**
6-10	18638	5301	696	473	8809	7438	**41355**
11-20	2390	209	96	122	1853	480	**5150**
21-50	369	50	38	23	497	95	**1072**

The analysis of data by scientific field (Table 4 and 5) indicates that the individual disciplines in different proportions publish papers with single or multiple authors. In humanities 85% of papers are signed by a single author, in social sciences 59%, in technical sciences 35%, in biotechnology 31%, in natural sciences 28%, and biomedicine and health 24% of papers are signed by a single author. Papers written in collaboration with 2 and 3 authors: in technical sciences 40%, in social sciences 36%, in natural sciences 32%, in biotechnology 24%, in biomedicine and health 20%, in humanities 13%. Papers written in collaboration from 4 to 10 authors: in biomedicine and health 52%, in biotechnological sciences 45%, in natural sciences 37%, in technical sciences 23%, in social sciences 5%, and in humanities 2%. Papers written in collaboration from 11 to 50 authors: in biomedicine and health 6%, in natural sciences 5%, in biotechnological sciences 1%, in technical sciences 1%, in social sciences and humanities 0.3%. Table 5. Multiple authorship



Rightfully we can ask ourselves if we can draw conclusions on the productivity of scientists in different scientific disciplines solely on the basis of the number of scientific papers, since the nature of multiple authorship is conditional on the organization of work in particular scientific fields.

In humanities 85% of publications have only one author, while in natural sciences only 28% of publications have one author, and in biomedicine and health only 24% of publications have a single author. On the one hand we have humanities and social sciences that have a small number of papers that have more than three authors (humanities 2.4% and social sciences 5%), on the other hand some scientific disciplines like biomedicine and health have 56.2% of the papers made in collaboration of four or more authors, then biotechnological sciences have 45.8%, and natural sciences have 40.3% of papers made in collaboration of four or more authors.

4. Conclusions

The most commonly used scientific communication channel of scientists in Croatia (in the period from 1997 to 2014) are papers in proceedings (38%), followed by papers in journal (32%), chapters in book 7%, books 3%, textbooks 1%, patents 0.1%.

Each scientific field prefers certain type of communication channel, so the journal is a primary form of communication in: natural sciences (39.4%) and humanities (36.0%); proceedings are primary form of communication channels in: technical sciences (46.0%), biomedicine and health (44.6%), biotechnical sciences (37.6%) and social sciences (34.4%).

In humanities and social sciences other communication channels are also essential, like chapters in a book and the book itself. Book chapter in humanities occurs 16.8%, and in social sciences 11%, while in other scientific fields occurs less frequently, in the range from 5.9% to 2.2%. The book as a communication channel is most common in humanities 6.6%, then in social sciences 4.4%, and in other scientific fields occurs in the range from 1.5% to 0.8%.

The difference in the nature of scientific disciplines and the organization of scientific work is also reflected in the observed multiple authorship. In humanities 85% of publications have only one author, while in natural sciences only 28% of publications have one author, and in biomedicine and health only 24% of publications have one author. On the one hand, we have humanities and social sciences that have a small number of papers that have more than three authors (humanities and social sciences 2.4% to 5%), on the other hand, some scientific disciplines like biomedicine and health have 56.2% papers in collaboration of four or more authors, then biotechnical sciences with 45.8% and natural sciences with 40.3% papers made in collaboration of four or more authors.

Differences in the dominant communication channels and multiple authorship in scientific fields indicate that it is difficult to devise universal bibliometrics (quantitative) criteria that could satisfy equal evaluation of all scientific disciplines. When selecting criteria for the evaluation the following must be taken into account: the nature of the scientific disciplines, the organization of scientific work and communication channels that correspond to the nature of scientific fields.

For the assessment of scientific production what is published is critical, and not where the paper is published. In a number of countries still dominates the "tyranny" of Impact Factor often as the sole criterion for the evaluation of scientific production and a key factor for the selection of scientists in scientific professions and it also serves as the crucial argument for funding research projects. Such use of Impact Factor, which evaluates the papers in journals as almost the only form of scientific communication, is in contrast with the presented data about the number of other forms of communications from proceedings, doctoral dissertations, books etc. In humanities books are represented with 6.6%, and in social sciences with 4.4%, which witness the importance of the book as a communication form, that inevitably must be respected and valued in these scientific fields.

Therefore, we agree with the position and basic messages of the declaration San Francisco Declaration on Research Assessment (2012) that has growing support of scientists and scientific institutions, Impact Factor must not be used "as a surrogate measure of the quality of individual research articles, to assess an individual scientist's contributions, or in hiring, promotion, or funding decisions." In short, we think that scientific disciplines should not be adjusted to evaluation criteria but evaluation criteria should be adjusted to the nature of scientific disciplines.

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