

## **RESEARCH OUTPUT OF CROATIAN UNIVERSITIES FROM 1996 TO 2004, REGISTERED BY THE SCIENCE CITATION INDEX-EXPANDED**

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### **SUMMARY**

The paper aims at assessing the research output of scientists working in “hard sciences” at six Croatian Universities (Dubrovnik, Osijek, Rijeka, Split, Zadar and Zagreb). The data obtained may serve as the starting point for further follow-up and in-depth studies of research performance at Croatian universities. This can be particularly relevant for implementation of the Bologna Process in Croatia. The methodology of the Academic Ranking of World Universities (2004) was applied (<http://ed.sjtu.edu.cn/rank/2004/Methodology.htm>). The number of papers published from 1996 to 2004, registered in the WoS-Science Citation Index-Expanded, authored by scientists from the six Croatian universities, was enumerated. Also, highly cited authors, authors of articles published in Nature and Science, Nobel Prize and Fields Medal winners were sought among these scientists. It was found that scientists at the Croatian universities produced 7527 of the total of 11068 articles authored by Croatian scientists. Of the six universities, the University of Zagreb was more productive than the remaining five. There were no highly cited authors, Nobel Laureates or Fields Medal winners from Croatia. One of 14 authors of an article in Science was from a Croatian university. Also, a letter on science policy, appearing in Nature, had one of two authors from Croatia. It can be concluded that scientists performing research in “hard sciences” at six universities in Croatia contributed about 68 % of all the articles published by Croatian scientists. University of Zagreb was the most productive.

### **KEY WORDS**

universities, ranking, Croatian universities, scientific productivity, bibliometric study

### **CLASSIFICATION**

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## **INTRODUCTION**

The first bibliometrically based evaluations of research institutions were carried out by Martin and Irvine in 1983, in the UK [1]. Since then numerous analyses of scientific productivity and institutional research output were published. The rankings, based on these analyses, were intended to identify excellence in these institutions and among researchers [2].

The academic ranking of world's universities was published in 2004 [3]. The ranking was based on four criteria: 1) Quality of education (alumni winning Nobel Prizes and Fields Medals); 2) Quality of faculty (staff winning Nobel Prizes and Fields Medals, and highly cited researchers); 3) Research output (articles in Science Citation Index – Expanded, Social Science Citation Index, and in Nature and Science); 4) Size of institution (academic performance related to size). The criteria under 2 and 3 carried 80 % of the weight.

Among the 500 most prestigious universities listed in the above ranking there were no universities from Croatia. Obviously, based on the above mentioned criteria, Croatian universities did not earn enough points to be included in the list. This induced us to examine the present standing of the Croatian universities, using the same criteria (see ref. [3]). We intended to collect data for an initial standing of the universities. These could be subsequently used to assess the development at the universities in the follow-up, as well as to gain certain deeper insights into the standing of each of the six Croatian universities and disciplines within them. The data thus obtained can be particularly relevant in relation to the implementation of the Bologna process in Croatia.

The overall productivity of Croatian scientists since Croatia's independence (year 1991) has been analysed in a few studies. They were based on both the national database [4, 5] and ISI databases [6, 7]. These studies indicated that general productivity and number of citations of Croatian scientists were below the average productivity of scientists in the world. Also, the internationally registered productivity of Croatian scientists in "hard sciences" was several times higher than the productivity of their colleagues in "soft sciences". Therefore, to begin with, we decided to concentrate on research performance of scientists conducting research in "hard sciences" at the Croatian universities.

## **UNIVERSITIES AND METHODS**

### **UNIVERSITIES**

There are six universities in Croatia: University of Dubrovnik, University of Osijek, University of Rijeka, University of Split, University of Zadar and University of Zagreb. The oldest among them is the University of Zagreb [8], founded in 1669 (modern university in 1874), whereas the youngest one is the University of Dubrovnik, founded in 2003 [9]. The Universities of Dubrovnik and Zadar started functioning independently in the year 2000, while formerly they had been part of the University of Split [10], founded in 1974. The University of Rijeka [11] was founded in 1973, and that of Osijek in 1975 [12].

The University of Zagreb has 29 faculties and academies, 20 of which belong to the category of "hard sciences" [8]. The University of Rijeka includes 10 faculties, 4 dealing with hard sciences [11]. Nine faculties constitute the University of Split, 6 offering programs in "hard sciences" [10]. Of the 10 faculties at the University of Osijek 7 are in "hard sciences" [12]. The University of Zadar has only one faculty (Faculty of Arts), whereas the University of Dubrovnik offers 6 study programs, 4 of which are in "hard sciences".

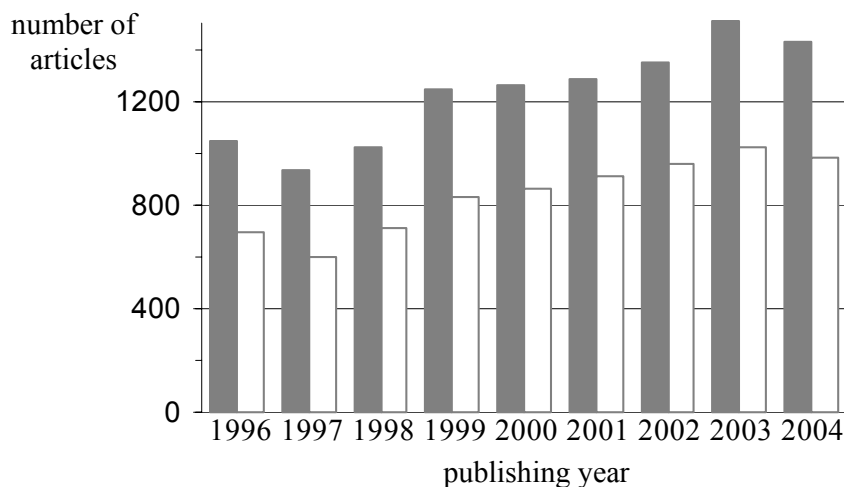
## DATABASE

We have used the WoS (Web of Science) version of the Science Citation Index-Expanded (Thomson-ISI, see [13] and [14]) to find author(s) with addresses in Croatia and at Croatian universities. The search was performed during January 2005. The search was performed during January 2005, using the WoS at Institute Rudjer Boskovic, <http://wos.irb.hr>. Names of authors were associated to their universities; a paper published by authors from more than one university was ascribed as one paper to each university. Articles published by Croatian universities' scientists in two prestigious science journals Nature and Science were counted separately. The research covered papers published in the period between 1996 and 2004. The year 1996 was chosen as the initial year since at that time one year passed after the Homeland War in Croatia had ended (August 1995).

In addition, we have searched the Thomson-ISI Highly cited researchers [15] to find out whether there were any highly cited scientists from Croatian universities. Furthermore, the lists of Nobel Prize [16] and Fields Medal [17] winners were checked (see Discussion).

## RESULTS

From 1996 to 2004, scientists with Croatian addresses published a total of 11 068 articles indexed in the SCI-expanded database. Among them 7527 papers have at least one author with the universities' address. Research output from Croatian universities related to the total output of Croatian scientists, working in "hard sciences", is depicted in Figure 1.



**Figure 1.** Total number of articles by author(s) from Croatia (grey boxes) and from Croatian Universities (white boxes), published between 1996 and 2004, registered in SCI-Expanded.

Clearly, the productivity of Croatian scientists in "hard sciences", during the whole period covered, depended heavily on contributions of scientists working at Croatian universities. The calculated average percentage (and standard error) during the period was  $0,68 \pm 0,02$ , indicating that about 68 % (range 67 to 73 %) of the total published papers came from authors working at the universities.

Next, we counted number of articles published by scientists from individual universities in the observed nine years. Besides the total number of articles produced by a given university, we also counted the number of articles for which the corresponding author was from the respective university. These data are presented in Table 1.

**Table 1.** Total number (**total**) of articles published annually by scientists from Croatian universities, indexed in SCI-Expanded, and the number of these articles for which the corresponding author (**corr**) was from the respective university.

Year	Univ. Zagreb		Univ. Osijek		Univ. Rijeka		Univ. Split	
	<i>Corr</i>	<i>total</i>	<i>corr</i>	<i>total</i>	<i>corr</i>	<i>total</i>	<i>corr</i>	<i>total</i>
1996	441	616	32	45	26	39	44	57
1997	386	576	9	13	9	17	17	22
1998	361	560	38	48	53	70	68	95
1999	465	678	45	60	42	63	61	75
2000	484	657	47	60	53	77	69	92
2001	518	744	29	51	58	84	57	77
2002	575	803	40	62	47	73	56	90
2003	532	821	47	69	49	72	73	108
2004	511	799	44	64	64	86	54	81

The University of Zagreb was several times more productive than the other three Croatian universities. Among the universities in Split, Rijeka and Osijek, the one in Split was consistently somewhat more productive than the other two. There is a tendency of increasing number of articles published during the nine years. The Universities of Dubrovnik and Zadar had too few indexed articles to be taken into account<sup>1</sup>.

Taking the number of published papers in 2004 and the number of teachers as potential authors in that year, one can arrive at the average number of papers per author in the Universities. The productivity per teacher was highest for the University of Zagreb (0,94 papers/author), whereas it was similar for other Universities: Split (0,22), Rijeka (0,21) and Osijek (0,18). In other words, almost every teacher at the University of Zagreb published at least one paper in 2004. In the other three Universities only one of five teachers authored one paper in the same year.

As additional indicators of the quality of articles published by researchers from Croatian universities, we used two more parameters (see ref. [3]): one was high citation of the published articles; another was publication of articles in Nature and Science. We found no authors from Croatian universities that were highly cited [15] during the observation period of nine years. During the same interval, there were two texts published in the two journals. Nature published a letter commenting science policy (Jonjić and Traven **429** (6992): 601, 2004), whereas an article, with one of 14 authors being from Croatia, appeared in Science (Semino et al, **290** (5494): 1155-1159, 2000). There were no Croatian scientists among Nobel Prize or Fields Medal winners [16, 17].

## DISCUSSION

Our intention was to assess the research output of scientists ("hard sciences") at all six Croatian universities, indexed in the Thomson Scientific/ISI WoS-Science Citation Index-Expanded, during the nine years after the Independence War in Croatia (1996-2004). We concentrated on "hard sciences" as previous studies consistently indicated strong predominance of these sciences [6, 7].

Our data demonstrate that the University of Zagreb was by far the most productive in the time interval. This is expected, since Zagreb University is the oldest and the largest of the six. It also has the largest number of faculties (20) in "hard sciences". Other universities are several times less productive, with the University of Split being slightly more productive than the other two. Here one should also take into account the number of faculties in hard sciences: Osijek has 7, Rijeka 4 and Split 6. The productivity of the six universities showed increasing tendency during the observation period of nine years. It constituted about 68 % of the total productivity of scientists with Croatian address. The University of Zagreb was the most productive in terms of the total number of papers published.

The small number of articles found eligible for consideration from the Universities of Dubrovnik and Zadar can be explained by the fact that Dubrovnik is the youngest university that, although it offers 4 study programs within the category of "hard sciences", has no organized faculties similar to the other universities, while the University of Zadar, on the other hand, has only one faculty, that of Arts.

Previous studies [6, 7] indicated that, in general, the productivity of scientists with addresses in Croatia was below the world's average. Further, papers published by these researchers were less cited than the world's average. In this study we did not attempt to assess the citation rate of papers published by scientists working at Croatian universities. However, since the universities contributed about 68% of all the papers published by Croatian scientists, it would be difficult to expect that their citation rate is significantly above the average citation rate of all papers published by Croatian scientists.

According to Bayers [18], in the period 1998-2002, ISI index included approximately 3,6 million papers: 1,3 million came from the EU member states (37 %), 1,2 million from the US (34 %). Contributions of some European countries were as follows: Netherlands 2,6 %, Sweden 2,1%, Switzerland 1,9% and Belgium 1,4%. Croatia contributed 0,18 %.

To comply with the described methodology (see [7]), we have taken three additional criteria employed in that study: the number of Nobel Prizes and Fields Medals, the number of highly cited authors, and the number of articles published in Nature and Science, the two prestigious science journals.

Croatia has no Nobel laureates in science. This statement requires a comment because two Croatian chemists actually received the Nobel Prize: Leopold Ružička (in 1939) and Vladimir Prelog (in 1975). Leopold Ružička was born in Vukovar (Croatia), and attended secondary school in Croatia, but his higher education and research, leading to the Prize, occurred outside of his homeland. Vladimir Prelog was born in Sarajevo (Bosnia and Herzegovina), studied chemistry and obtained his Ph.D. degree at the Technical High School in Prague (Czech Republic). Since 1935 Prelog was professor of Organic chemistry at the University of Zagreb, from where he migrated to Switzerland at the beginning of the Second World War.

As for the Fields Medal, no Croatian scientist was listed among the winners. Also, no scientists with a Croatian address were ranked by the Thomson-ISI Highly cited ranking. As we have mentioned above, there was one letter (not a new scientific information) published in Nature by the author employed at one of the universities. Also one of 14 authors of an article appearing in Science has an address at one of the universities.

Our study indicated that, among scientists doing research in "hard sciences" at the six universities in Croatia, those at the University of Zagreb were most productive. This university is also the oldest and the largest in Croatia. The universities in Osijek, Rijeka and Split had a similar productivity, with the slightly higher productivity of the University of

Split. The productivity of the six universities had an increasing tendency during the observation period of nine years.

We concluded that the relatively low productivity of researchers from the Croatian universities, lack of highly cited papers and of Nobel Prize and Fields Medal winners can explain that none of the Croatian universities was included among the world's 500 most prestigious universities (see ref. [7]). Based on the present study, we will continue tracing the same parameters to detect their possible changes. Also, we will try to use them for more in-depth analyses of individual scientific disciplines within the universities. These data are particularly relevant at the time of implementation of the Bologna Process in Croatia in the context of pre-accession negotiations for European Union membership.

## NOTE

<sup>1</sup>We also intended to present the average number of papers per author at individual universities, however, we were unsure whether the available official data on the number of teachers were standardized enough to allow such a comparison.

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## ZNANSTVENA PRODUKTIVNOST HRVATSKIH SVEUČILIŠTA OD 1996. DO 2004., REGISTRIRANA U SCIENCE CITATION INDEX-EXPANDED

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### SAŽETAK

Namjera nam je bila ustanoviti znanstvenu produktivnost znanstvenika koji se bave „čvrstim znanostima” na šest hrvatskih sveučilišta (Dubrovnik, Osijek, Rijeka, Split, Zadar i Zagreb). Rezultati bi mogli poslužiti kao polazište za buduće praćenje i dublje analize znanstvene produktivnosti na Sveučilištima. To bi moglo biti posebno važno pri primjeni Bolonjskoga procesa u Hrvatskoj. Primijenjena je metodologija iz *Academic Ranking of World Universities* (2004.) (<http://ed.sjtu.edu.cn/rank/2004/Methodology.htm>). Izbrojen je broj članaka koje su, od 1996. do 2004., objavili znanstvenici iz šest hrvatskih sveučilišta, registriran u *WoS – Science Citation Index – Expanded*. Uz to se tražilo ima li među tim znanstvenicima onih koji su citirani osobito često, koji su objavili svoje članke u *Nature* i(li) *Science*, koji su dobili Nobelovu nagradu ili Fieldsovu medalju. Znanstvenici na hrvatskim sveučilištima objavili su 7527 članaka od ukupnih 11068 članaka kojima je bar jedan autor s adresom u Hrvatskoj. Od šest Sveučilišta, Sveučilište u Zagrebu bilo je nekoliko puta produktivnije od preostalih pet; i po apsolutnome broju članaka i po broju članaka po pojedinome znanstveniku. Među znanstvenicima sa Sveučilišta nije bilo osobito često citiranih autora, ni dobitnika Nobelove nagrade, ni Fieldsove medalje. Jedan je od 14 autora jednoga članka objavljenog u *Science* imao adresu na jednom od Sveučilišta. Pored toga, jedan je od dvojice autora pisma o znanstvenoj politici, objavljenoga u *Nature*, bio sa hrvatskoga sveučilišta. Zaključeno je da su znanstvenici koji se bave „čvrstim znanostima” na šest hrvatskih sveučilišta, u odabranome razdoblju, objavili oko 68 % svih članaka koje su objavili hrvatski znanstvenici. Pri tome je Sveučilište u Zagrebu bilo najproduktivnije.

### KLJUČNE RIJEČI

sveučilišta, rang, Hrvatska sveučilišta, znanstvena produktivnost, bibliometrijsko istraživanje