Scientometrics, Vol. 32, No. 2 (1995) 133-152

ANALYSIS OF THE SCIENTIFIC PRODUCTIVITY OF RESEARCHERS FROM THE REPUBLIC OF CROATIA FOR THE PERIOD 1990-1992

B. KLAIĆ

Ruder Boškovic Institute, 41000 Zagreb, P.O. Box 1016 (Croatia)

(Received August 3, 1994)

The scientific production of researchers from the Republic of Croatia, consisting of the published papers with addresses of the institutions from Croatia only, was analyzed for the period 1990-1992, covering 2047 *SCI, SSCI,* and *A&HCI* registered papers. The source index of *SCI* has registered 1912 (92.50% of total number of published articles) papers, *SSCI* 118 (5,71%), and *A&HCI* 37 (1.79%) papers, respectively. The papers were published in more than 700 different journals, covering 122 scientific subfields. The most frequently used journals are the national *Periodicum Biologorum, Croatica Chemica Acta* and *Collegium Antropologicum* with 236 published papers or 11.5%. The largest number of papers have been published in scientific subfields: *Biology* (146 papers), *Chemistry* (107), and *Physics of Condensed Matter* (102). The average paper was published by 3.57 researchers, but subfields of *Nuclear Physics* (7.40 authors per paper), *Immunology* (5.67), and *Hematology* (5.60) were with the highest authorship. The partial contributions of institutions were also determined, and the most productive were Ruder Bošković Institute with 645.0, the Faculty of Medicine with 396.7, and the Faculty of Science and Mathematics with 201.7 published papers, respectively. The average quality of the used journals were estimated; Institute of Physics, Ruder Bošković Institute, and the Faculty of Science and Mathematics published their papers in journals with bigger impact factor (higher quality) than average institutions. Publications were divided by the type of papers, most frequent being articles (1778 publications, 86.85%), notes (117, 5.71%) and letters (56, 2.74%), respectively. Scientific subfield distribution of papers published by the most productive institutions were also analyzed.

Introduction

A few years ago, more than 85% of the research papers were published in twelve most scientifically productive countries (USA, UK, USSR, Japan, Germany FR, France, Canada, India, Italy, Australia, Netherlands and Sweden).[1] Most of these countries were the richest and the most advanced countries of the world, and consequently much of the world literature on the scientific productivity of different nations is on science in these developed world. Smaller attention has been paid to scientific output of scientifically middle level countries, and production of their institutions.[2-7] Although, in the last two decades scientists from Croatia have

published more than one hundered scientometric papers, most of them have been published in Croatian in domestic journals, and covered a relatively narrow part of science, like medicine[8,9] chemistry,[10] biology,[11] or they analyzed the scientific activity of one institution.[12-14]

On the other hand, in the last few years dramatic political changes happend, especially in Europe where several European countries ceased to exist (USSR, Czechoslovakia, Yugoslavia and German DR). These changes obviously had some influence on the world country ranking of published papers. The Republic of Croatia became an independent country, internationally recognized in 1991, by desintegration, unfortunately through war, of former Yugoslavia which was artificially created after the first world war in 1918.

The Republic of Croatia is a small, developing country with 4.8 millions of inhabitants, contributing with 0.09% in total population of the world. The other socio-economic indicators are given in Table 1.

Table 1
Social and economic indicators of Republic of Croatia[2,3]

Area, km²	56538
Population, (1991), thousand	4784
Life expectancy at birth (1991), male, years	67.0
Life expectancy at birth (1991), female, years	74.0
Gross domestic product (1990), million US $	20900
Per capita GNP (1990), US $	4400
Annual growth rate (1985-1989), %	0.0
Adult literacy (1991), %	94.4
No. of TV sets per thousand people (1991)	214
Total No. of newspapers (1991)	9
No. of newspapers sold daily per thousand people (1991)	130
No. of telephones per thousand people (1991)	229
No. of cars per thousand people	180
No. of students in primary school, thousand	497.8
No. of students in secondary school, thousand	215.4
No. of students of higher level, thousand	70.8
No. of physicians per thousand people	2.13
Per capita energy consumption, KW-hr equivalent	2046
Percentage of population between 15 and 64 years (1991), %	67.5
Economically active population (1991), thousand	1509
Unemployment rate (% of total labor)	20.3
Total No. of potential scientists-engineers/technicians (1991)	14145
Scientists/technicians personnel deployed in R&D (1991), per thousand	2.95
Per capita expenditure on R&D per annum (1991, US $)	19.6

The Republic of Croatia has 166 scientific organizations and research units, which can be divided into 74 scientific institutes, 25 research units, and 66 university-level educational institutions. The staff of these institutions comprises the total of 18361 full-time employees, 8709 of them being researchers with university level education while 4336 of them are technicians. In addition, these research units have 1100 part-time employees with university level education, giving a total number of around 10000 researchers. The full-time researchers are represented by 3293 scientists with Ph.D., 2266 with M.Sc., 142 persons with specialized training, and 3008 with bachelor's degree. All scientific units can be divided into 18 units engaged in natural sciences employing 969 full-time researchers, 52 units in technical sciences with 3280, 29 units in medical sciences with 144, 22 units in biotechnology with 836, 36 units in social sciences with 1407, and 8 units in humanities with 775 researchers.[15]

In this paper the total scientific production of researchers from the Republic of Croatia whose papers were published with addresses of institutions from Croatia and were covered by Source Indexes of the *Science Citation Index, Social Science Citation Index,* and *Arts & Humanities Citation Index,* for the period 1990-1992, is analyzed. The distribution of publications with respect to the scientific subfield, journals used and scientific organizations are also identified.

Methodology

This evaluation of scientific productivity of researchers from the Republic of Croatia is based on publication data, which were collected from the publications of Institute for Scientific Information (ISI; Philadelphia, USA): Geographic Section of the Corporate Index and Source Index of the *Science Citation Index (SCI), Social Science Citation Index (SSCI),* and *Arts & Humanities Citation Index (A&HCI),*[17-19] respectively, for the period 1990-1992. The published papers were classified according to subfields used in *Journal Citation Reports (JCR,* Section 8),[20] or Source Publications arranged by subject category of *SCI Guide*,[21] *SSCI Guide*,[22] and *A&HCI,* respectively. When a particular journal appeared in ISI publications in two different subfields, in this paper it was classified in the larger subfield.

In the case of partial authorship of a published paper only those with domestic addresses, are recognized; publications published by three addresses give 0.33 papers to each scientific organization, regardless of the number of authors from the particular institution.

The concept of "pure paper" is introduced, comprising from articles, notes and letters. The total number of published papers include "pure papers" and all other types of publications. Reviews were omitted from this category, at the first place, because they are mostly dealing with consideration of previously reported results.

The quality of journals used for publishing papers was classified in four categories. The first quality group of journals is comprising from the first 10% journals ranked by impact factor within the particular scientific subfield. The second quality group includes the next 20% of journals, the third group forms further 30%, while the fourth group contains the last 40% of journals ranked by the impact factor. The usage of quality groups makes possible the comparison of quality of journals between different scientific subfields, which have a large difference of impact factors. The first quality group is marked by the numeric value 1, second 2, third 3 and fourth 4, respectively. Smaller numeric values of a particular subfield means a better quality of the used journals.

Results and discussion

During the three years period 1990-1992, 2047 papers with institution addresses within the Republic of Croatia covered by Source Indexes of *SCI, SSCI,* and *A&HCI* were published (Table 2). Some of these papers were covered by two (16 papers) or three (2 papers) indexes. Most of them (1912 papers, 92.50% of total number) were covered by *SCI*, 118 of them (5.71%) by *SSCI*, and 37 (1.79%) by *A&HCI*. The number of "pure" papers is 1951, which is 95.31% of the total number of published papers. The major part of these papers (1844, 93.75%) is covered by *SCI*. In the same three-years period the number of full-time researchers employed with croatian scientific institutions was practically unchanged and slightly smaller than 9000 persons. The publication count of 2047 papers covered by ISI gives the productivity of 0.078 ($2047/3 \times 8709$) papers per research-year, what is significantly lower than the world average value of 0.80 paper per research year, this has been calculated from Comparative statistical summary of *SCI*, 1990-1992,[21] or 1.02 paper per research year from Comparative statistical summary of *SSCI*, 1990-1992.[22] However, for the year 1990, Unesco[23] estimated that world total is 5.22 millions researchers whereas for the same year ISI publications[19, 21, 22] covered 814 thousand publications (591 in *SCI*, 121 in *SSCI*, and 102 thousand in *A&HCI*). These two numbers give the productivity of 0.156 papers per research-year. If the comparison of productivity between researchers from Croatia (0.078) and the world average (0.156) is done in this way,

we can assume that a more objective picture is obtained, the world average productivity being two times higher than Croatian's. However, at this point we have to take into account that around 80% of world researchers are completely "invisible" in the year 1990. Similar value can be observed for the researchers from Croatia.

Table 2

Classification of papers published with addresses of the Institutions from the Republic of Croatia collected from Source Index of the *Science Citation Index (SCI), Social Science Citation Index (SSCI),* and *Arts & Humanities Citation Index (A&HCI),* for the period 1990-1992

Source Index of	Number of papers	% of total	Number of "pure" papers	% of total
SSCI	103	5.03	87	4.46
SSCI & SCI	8	0.39	7	0.36
A&HCI	27	1.32	17	0.87
SSCI & A&HCI	5	0.24	4	0.21
SSCI, SCI & A&HCI	2	0.10	2	0.10
SCI & A&HCI	3	0.15	3	0.15
SCI	1899	92.77	1831	93.85
Total	2047	100.00	1951	100.00

Schubert and *Telcs*[24] studied the problem of different indicators in national and international collection of science statistics and introduced a more objective indicator – *publication potential.* Their study gives four relevant indicators for 85% of world science (the first 35 countries) in the year 1979: author count of 391 thousands, publication count of 690 thousands, publication potential of 1464 thousands, whereas the Unesco estimates that these countries have 3325 thousands scientists. From these data it can be concluded that about 45% (1464/3325) of total number of researchers should be "visible" in science during their researchers careers, although in this particular year only 12% (391/3325) of researchers are "visible". This value has to be increased for approx. 40%, because only 70% of world scientific output is covered by *SCI,* whereas the rest is covered by *SSCI* and *A&HCI.* From this fact one can expect that around 17% (0.12/0.7) of scientists are "visible" in a particular year, and approx. 65% of the total number of researchers would be covered by ISI publications during their researchers careers.

If the total number of croatian researchers are divided to persons who are working in the scientific fields covered by *SCI,* one can obtain 6527 researchers (74.9% of total number) who published 1912 papers (92.5% of total number) with

productivity of 0.098 paper per research year, what is approx. 65% of the world average. The situation with scientific productivity in the fields covered by *SSCI* and *A&HCI* is dramatically different. Productivity of 1407 researchers (16.2%) covered by *SSCI*, who published 118 papers (5.7%), is 0.028 papers per research year, whereas in fields covered by *A&HCI* are working 775 researchers (8.9%) and 37 papers are published giving a productivity of 0.016 paper per research year. The reason for poor production in social sciences and humanities lies probably in the practice of researchers to publish in domestic journals, and in the Croatian language. The similar observation has been published for Netherlands social science departments which published more than 60% of their papers in Dutch.[25] On the other hand, the Marxian doctrine, the official ideology until 1991, cannot be excluded, as one of reasons of low productivity in the international literature.

During the observed period *SCI*[21] covered 1.81, *SSCI*[22] 0.36 and *A&HCI*[19] 0.34 million authored source items. The Republic of Croatia contributes in the total world population with 0.09%, and on this base it is rational to expect a production of 1627 papers covered by *SCI,* 325 by *SSCI,* and 306 by *A&HCI,* respectively. The production of papers covered by *SCI* is 17.5% higher than could be expected, whereas the production of *SSCI* covered papers is 36.3%, and of *A&HCI* 12.1% of the expected values.

For the year 1990, Unesco[23] reports that the total R & D expenditure was approx. 453 billion U.S. dollars, giving an amount of 86.600 per one researcher, or 556.000 U.S. dollars per one ISI covered paper. In the year 1991, Croatian expenditure for science was 94 million U.S. dollars[15] only, or about 10.800 dollars per researcher, whereas the average in developing countries was 24.100 and 15.600 dollars per researcher from Africa, respectively. An average Croatian ISI covered paper costs about 138.000 dollars or 24% of world average.

Table 3 analyzes the type of published papers and shows the difference between distribution of Croatian and world publications. Three of the most used types of publications are articles, notes and letters, representing 95.30% of the total number of all papers, while for publications covered by *SCI* only, the number of these three types of papers increased to 96.38%.

Table 3
Analysis of type of the published papers with address of the institution from the Republic of Croatia

Type of paper	Abb	Total	%	SCI[a]	%	SCI[b]
Article	-	1778	86.85	1675	87.60	72.72
Meeting abstract	M	33	1.61	29	1.52	8.19
Note	N	117	5.71	114	5.96	6.45
Letter	L	56	2.74	54	2.82	5.51
Editorial	E	20	0.98	16	0.84	3.47
Review	R	21	1.03	20	1.05	2.11
Book review	B	18	0.88	-	0.00	0.09
Discussion	D	3	0.15	3	0.16	0.23
Biographical item	I	1	0.05	1	0.05	0.28
Total		2047	100.00	1912	100.00	99.15

Abb = Abbreviation of ISI source item code.
Total = Total number of papers from Source Index of the *SCI, SSCI,* and *A&HCI,* for the period 1990-1992.
SCI[a] = Total number of papers from Source Index of the *SCI* only.
SCI[b] = World distribution of source items from *Journal Citation Reports,* 1991.

Contribution of articles in Croatia is approx. 20% higher than in the world scientific output, while all other types of publications are rarely represented by croatian papers. Contribution of meeting abstracts is less than 20% and editorials about 25% of world average, respectively. There are two major reasons for the small number of meeting abstracts in the total production. The first is that *SCI,* beginning in 1989, covered meeting' abstracts from the selected group of 500 journals and not from all journals, the second, because of insufficient funding of science in Croatia and consequently domestic researchers cannot afford to participate at expensive international meetings which are covered by the 500 journals. Considering that part of editorials are connected with meetings, we can use the same explanation.

The number of authors per publication was also taken into account, the average Croatian paper had 3.57 authors (Table 4), which is a little higher than the world average of 3.26 authors per *SCI* covered paper,[21] and more than in previous studies for chemists from Croatia (2.8)[7] or from the RBI (2.78 and 3.05).[13, 14] Most of the papers were published by one to five authors (85.85%), whereas 57 (2.78%) papers were published by ten or more authors; papers published in social sciences and humanities are single-author or two-authors publications and consequently the authorship average of *SCI* covered papers is somewhat higher. A general tendency to

multiple authorship of papers in science can be observed; for example a paper published in 1964 had on average 1.96 authors, as compared to 2.56 in 1980 or 3.36 in 1992,[21] obviously because of team-work, depending on the subfield. Both papers with 24 and 74 authors, respectively, were published in the subfield *Nuclear Physics.*

Table 4
Classification of published papers with respect to the number of authors per publication

Number of authors per published paper	Number of papers	% of total	Number of "pure" papers	% of total
1	289	14.12	249	12.76
2	439	21.44	419	21.48
3	466	22.77	454	23.27
4	365	17.83	354	18.14
5	207	10.11	199	10.20
6	112	5.47	110	5.64
7	51	2.49	51	2.61
8	46	2.25	43	2.20
9	15	0.73	15	0.77
10	28	1.37	28	1.44
11	8	0.39	8	0.41
12	8	0.39	8	0.41
13	6	0.29	6	0.31
14	2	0.10	2	0.10
15	1	0.05	1	0.05
17	1	0.05	1	0.05
19	1	0.05	1	0.05
24	1	0.05	1	0.05
74	1	0.05	1	0.05
Total	2047	100.00	1951	100.00
Arithmetic mean of authors per publication	3.57		3.63	

Introduction of the numeric value of indicator *quality of journal* can help in comparison of journals from different subfields, which have very heterogeneous average impact factors. But it should be kept in mind that generally journals with higher impact factors in a particular subfield publish in average more papers than journals with lower impact factors, and as a consequence, the average value of all journals are slightly below the numeric value 3, which is an arithmetic mean. Researchers from Croatia published their papers in 715 journals, but ten or more papers were published in only 31 journals, with an average quality rank of around 3.

Most of them are in the major field *Physics* and *Chemistry* (Table 5). In the first five used journals there are four domestic and one international journal (*Phys. Rev. B.* in subfield *Physics of Condensed Matter*), and three of these domestic journal have quality rank 4, and only *Croatica Chemica Acta* has a quality rank 3 (of the last ten years eight years had the quality rank 3 and two years 4). These journals covered 14.70% of published papers, and have the average quality of 3.57. The most frequently used journal, the domestic *Periodicum Biologorum,* published 139 papers or 6.79% of the total number of publications. There were 403 journals (56.36% of the total number of journals) in which only one paper was published, and 128 of them with two papers, covering 74.27% of the total number of used journals, and 32.19% of the total number of publications. Almost all published papers covered by the three ISI indexes were published in English.

Table 6 shows the scientific subfield distribution of published papers, the average quality of the used journals and the average number of authors per publication. There are only 34 subfields with 20 or more papers, but they cover 76% of the total number of publications. If we assume that the distribution of publications in the major fields during the observed period 1990-1992 is similar as given by *Schubert* et al.[1] (1981-1985), 55.0% of papers in the major field *Life,* 19.1% in *Physical,* 13.2% in *Chemical Sciences,* 10.2% in *Engineering,* and 2.5% in *Mathematics* can be expected. However, the distribution of croatian papers is completely different: the major field *Life sciences* covers 46.3%, *Physical sciences* 26.5%, *Chemical sciences* 21.1%, *Engineering* 4.7%, and *Mathematics* 1.4%. The *Physical* and *Chemical sciences* show a production of approx. 50% higher, while in *Mathematics* and especially *Engineering* there is less productivity than expected from the world distribution (all data not shown in Table 6). The contribution of the major field *Life sciences* of croatian scientific output (46.3%) is similar to the percentage ratio of Hungary (46.6%), Portugal (43.6%), German Democratic Republic (43.3%), or Czechoslovakia (44.5%).[1] In the major field *Chemical sciences* (21.1%) Croatia is most similar to German Democratic Republic (21.4%, whereas the contribution of *Phisical sciences* (26.5%) is similar to the output of Portugal (24.3%) or Greece (25.5%).[1] *Bonitz* et al.[26] introduced a new indicator, *Science Strategy Index* (SSI), which is based on the comparison of a country's science activity over all science fields and related to the world distribution of the science fields. The SSI of the Republic of Croatia is 84.7, what is higher than the same index of former Yugoslavia (83.0), and similar to Czechoslovakia (83.9), Hungary (84.1), or Greece (84.5).

Table 5

Classification of journals with respect to the number of published papers, rank of quality of the journals and scientific subfields

Journal	Number of papers	Quality rank of journal	Scientific subfield
Per biol*	139	4	Biology
Croat Chem*	58	3	Chemistry
Coll Antrop*	39	4	Antropology
Phys Rev B	35	2	Physics of Condensed Matter
Act Pharma*	30	4	Pharmacology & Pharmacy
Mar Chem	24	2	Oceanography
Phys Rev C	22	3	Nuclear Physics
Act Cryst C	21	4	Crystallography
J Elec Chem	20	2	Analytical Chemistry; Electrochemistry
Nucl Inst B	20	2	Instruments & Instrumentation
Mutat Res	19	3	Genetics & Hereditary
Theochem	18	4	Physical Chemistry
Bone Mat Tr	19	3	Immunology
Nucl Phys A	16	3	Nuclear Physics
Sol St Comm	16	3	Physics of Condensed Matter
J Mol Struc	15	3	Physical Chemistry
J Magn Mag	14	2	Material Sciences
Synth Met	13	4	Physics of Condensed Matter
Analyt Chim	12	3	Analytical Chemistry
Nucl Inst A	12	2	Instruments & Instrumentation
J Perin Med	11	4	Opstetrics & Gynecology
Phys Lett B	11	1	Physics
Physica C	11	3	Physics
Radiocarbon	11	3	Geosciences
Vaccum*	11	4	Applied Physics
B Envir Con	11	3	Environmental Sciences
Angew Makr	10	4	Polymer Science
Phys Rev A	10	2	Physics
Phys Rev L	10	2	Physics
Z Phys A	10	3	Nuclear Physics
Z Phys D	10	4	Atomic, Molecular & Chemical Physics

*Journal published in the Republic of Croatia.

In the Table only journals with 10 or more published papers are included.

Scientific subfields were taken from *SCI Journal Citation Reports* and *SSCI Journal Citation Reports*, respectively.

Table 6

Scientific subfield distribution of papers published by authors from the Republic of Croatia with domestic addresses

Scientific subfield	Number of papers	Average quality	Average number of authors	Number of "pure" papers	Average quality	Average number of authors
Biology	146	3.92	3.85	145	3.92	3.87
Chemistry	107	2.78	3.09	100	2.77	3.08
Physics of Condensed Matter	102	2.29	3.38	99	2.30	3.41
Physical Chemistry	90	2.79	3.56	85	2.76	3.62
Analytical Chemistry	64	2.95	2.81	64	2.95	2.81
Pharmacology & Pharmacy	64	3.55	3.64	60	3.52	3.77
Physics	63	1.92	3.71	60	1.93	3.78
Nuclear Physics	57	2.75	7.40	57	2.75	7.40
Anthropology	53	3.92	2.19	41	3.97	2.24
Biochemistry & Molecular Biology	45	3.07	4.18	43	3.05	4.28
Environmental Sciences	44	2.75	2.57	44	2.75	2.57
Applied Physics	43	2.40	3.91	43	2.40	3.91
Radiology & Nuclear Medicine	41	1.95	3.37	36	1.97	3.14
Instruments & Instrumentation	41	2.46	5.46	40	2.45	5.55
Organic Chemistry	41	2.83	3.66	41	2.83	3.66
Chrystallography	41	3.20	3.46	41	3.20	3.46
Oncology	38	2.92	4.61	38	2.92	4.61
Immunology	36	2.89	5.67	35	2.89	5.77
Inorganic & Nuclear Chemistry	35	2.97	3.97	35	2.97	3.97
Polymer Science	34	3.03	3.53	34	3.03	3.53
Atomic, Molecular & Chem. Physics	34	2.94	3.23	33	2.91	3.18
Oceanography	33	1.30	3.24	32	1.31	3.31
Genetics & Heredity	32	2.81	3.81	28	2.86	3.86
Electrochemistry	32	2.38	2.66	32	2.38	2.66
Obstetrics & Gynecology	28	3.29	3.68	28	3.29	3.68
General & Internal Medicine	27	2.15	4.18	23	2.13	4.57
Materials Science	27	2.48	3.78	27	2.48	3.78
Food Science & Technology	25	2.76	2.76	24	2.75	2.83
Neurosciences	25	2.80	4.36	24	2.88	4.46
Astronomy & Astrophysics	23	3.22	3.48	23	3.22	3.48
Arts & Humanities	23	4.00	1.04	13	4.00	1.08
Geosciences	21	2.95	3.62	19	2.86	3.79
Hematology	20	3.10	5.60	11	3.18	6.73
Public Health	20	2.25	4.45	20	2.25	4.45
All other (88 subfields)	492	2.78	3.06	473	2.84	3.10
TOTAL	2047	2.86	3.57	1951	2.86	3.63

Starting from Schubert's, Glänzel's and Braun's definition of activity and attractivity indexes,[1] we can introduce numerical values; subfields with productivity of two times higher than is the world average have extremely high activity, fields with 125 to 200% have high activity, average activity with 75-125%, low activity with 25-75%, and extremely low activity with less than 25% of world average. From the world scientific subfield distribution[1] the theoretical number of Croatian papers in particular subfields was calculated (data is not shown) and after comparison with the real number of publication, it can be established that the subfields with extremely high activity are: *Electrochemistry* (3.55, more than the theoretical number), *Chrystallography* (3.41), *Physics of Condensed Matter* (2.83), *Oceanography* (2.75), *Environmental Sciences* (2.44), *Physical Chemistry* (2.31), whereas *Analytical Chemistry* (2.00) is at the border of extremely high and high activity. Neither of the shown subfields is in the group of extremely low activity, whereas groups with low activity are *General & Internal Medicine* (0.31), *Biochemistry & Molecular Biology* (0.43), and *Neurosciences* (0.44).

The scale of numeric values of journal quality is not linear, and we can assume that subfield with extremely high attractivity has the numeric value of a journal quality between 1.0 and 1.5, high attractive field of 1.5-2.3, average 2.3-3.0, low attractive 3.0-3.5, and extremely low attractive field has numeric value of journals over 3.5. The field with extremely high attractivity in Croatia is *Oceanography* (1.30), whereas *Physics* (1.92), *Radiology & Nuclear Medicine* (1.95), *General & Internal Medicine* (2.15), *Public Health* (2.25) and *Physics of Condensed Matter* (2.29) are in groups of subfields with high attractivity. *Schubert* et al.[1] have established for former Yugoslavia that most of the mentioned subfields had high activity and high attractivity. Fields with extremely low attractivity are *Biology* (3.92) and *Anthropology* (3.92). Most of papers from the last two subfields are published in domestic journals *Periodicum Biologorum* and *Collegium Antropologicum.* Generally, one can say that higher activity is bound with higher attractivity, with exception of the subfield *Chrystallography,* which high activity has not as a consequence high attractivity.

In the first five scientific subfields (in field of Chemistry, Physics and Biology) were published 471 paper or 23.01%, while 88 of the less productive subfields included 492 papers (24.04% of total number of papers). The average quality of the used journals varied from 1.30 for the subfield *Oceanography* to 3.92 for *Biology.* For journals covered by *A&HCI* the average quality was taken 4, because of unaccesibility of their impact factors. The most "researcher-time-consuming" papers were published

in subfield of *Nuclear Physics* with 7.40, *Immunology* with 5.67, *Hematology* with 5.60, and *Instruments & Instrumentation* with 5.46 authors per paper (Table 6). The average quality of the used journals is the same for all and for "pure" papers (2.86).

The five most productive scientific institutions, which have published more than 100 papers in the three years period are Ruder Bošković Institute (RBI), the Faculty of Medicine (Zagreb; FM). the Faculty of (natural) Science and Mathematics (FSM), Institute of Medical Research and Occupational Health (IMR), and Institute of Physics (IP). These institutions published all together 1452.7 papers or 70.97% of the total number of publications (Table 7). The total number of employees in these institutions is less than 2000 researchers, with production of at least 0.24 papers per research year. The most productive, RBI, with around 480 scientists, has a productivity of about 0.45 papers per research year. This productivity is somewhat lower than found for chemists from the RBI (0.57),[14] but it should be kept in mind that only approx. 80% papers of authors from the RBI were published with RBI address. Results obtained for "pure" papers are the same. There is a big difference in scientific production between institutions, for example three of the biggest and most productive scientific institutes with approx. 700 researchers (IP, IMR, and RBI) published almost all papers from all scientific institutes. Other 20 smaller scientific institutes have at least the same number of researchers, and each institute published on average one paper in three years. Twenty five faculties from the University of Zagreb, published in average less than 1.5 papers yearly, but they have at least half of all employed researcher. The production of institutes or research units in industrial companies is less than 4% of the total number of papers. Similar situation is with three smaller and younger universities of Rijeka, Split and Osijek. The total number of researchers employed in these universities is approx. 40% of researchers from the University of Zagreb, but their scientific output is only 15% of the Zagreb University production.

The first three institutions (which were able to publish more than 50 papers per three years period) with regard to quality of used journals are: IP (2.41), RBI (2.65) and FSM (2.71). These institutions if taken together, have approx. 900 researchers (10% of total number) and published 953.5 papers (46.58% of the total number), with a productivity of at least 0.35 paper per year, the average quality of the used journals being 2.67. Other institutions having approx. 7700 researchers published 1093.5 papers with a productivity of 0.05 papers per research year, and the quality of the used journals was 3.04. On the other hand, the comparison of "pure" paper productivity revealed that RBI produces almost the same number of publications as

the University of Zagreb, which has at least eight times more researchers (approx. 3800) or 2.7 times more research-years than RBI, because there is an official assumption that scientists from universities spent two thirds of their time on education and only one third for research.

The distribution on scientific subfields of nine most productive institutions in Croatia, which comprise around 80% of the total scientific output, is given in Table 8. On the first sight it can be seen that there are several institutions like IP, FPB and IMR which are more specialized, whereas some other institutions are less specialized. In the 34 largest scientific subfields the above mentioned institutions published 79%, whereas 21% of their papers were published in 88 subfields, which are not shown in Table 8. Other 106 institutions published 65% of papers in the 34 largest subfields.

The RBI published more than 50% of the total Croatian output in the following subfields: *Instruments & Instrumentation* (72%), *Oceanography* (61%), *Physical Chemistry* (60%), *Applied Physics* (56%), *Electrochemistry* (54%), *Atomic, Molecular & Chemical Physics* (53%), *Biochemistry & Molecular Biology* (53%), *Chemistry* (52%), *Physics* (50%), whereas the FM published 82% in *Obstetrics & Gynecology*, 60% in *Immunology*, 57% in *Oncology, Radiology & Nuclear Medicine*, *Neurosciences*, and *Hematology*. On the other hand, the highly specialized IP, 47% of its output was published in the subfield of *Physics of Condensed Matter*, whereas the FPB published 43% of its papers in *Pharmacology & Pharmacy*.

Table 7

Scientific productivity of institutions from the Republic of Croatia in the period from 1990 to 1992.
Papers were collected from Source Index of the *SCI*, and *A&HCI*

Institution	A	% of total	B	% of total	C	D	%	E	%	F
Institute of Physics	116	4.73	106.8	5.22	2.41	112	4.76	102.8	5.27	2.42
Institute of Medical Research	126	5.14	102.5	5.01	3.14	122	5.19	98.5	5.05	3.13
"Ruđer Bošković" Institute	731	29.80	645.0	31.51	2.65	709	30.16	624.5	32.02	2.64
Other 20 scientific institutes	21	0.86	20.0	0.98	3.24	13	0.55	12.5	0.64	2.77
Total scientific institutes	**994**	**40.52**	**874.3**	**42.71**	**2.70**	**956**	**40.66**	**838.3**	**42.98**	**2.68**
Faculty of Pharmacy & Biochem.	64	2.61	49.2	2.40	3.33	60	2.55	45.7	2.34	3.28
Faculty of Medicine	452	18.43	396.7	19.38	3.05	428	18.21	374.2	19.18	3.10
Faculty of Food Tech. & Biotech.	28	1.14	21.7	1.06	3.11	27	1.15	20.7	1.06	3.11
Faculty of Geodesy	25	1.02	20.2	0.99	3.08	25	1.06	20.2	1.04	3.08
Faculty of Sciences & Mathemat.	261	10.64	201.7	9.85	2.71	251	10.68	192.7	9.88	2.71
Faculty of Technology	83	3.38	62.7	3.06	3.08	82	3.49	61.7	3.16	3.09
Univer. of Zagreb (no address)	35	1.43	34.3	1.68	3.43	24	1.02	23.3	1.19	3.25
Faculty of Veterinary Sciences	22	0.90	14.2	0.69	3.09	22	0.94	14.2	0.73	3.09
Other 25 faculties	94	4.20	72.5	3.54	2.81	89	3.78	68.0	3.49	2.81
Total University of Zagreb	**1064**	**43.38**	**873.1**	**42.65**	**2.98**	**1008**	**42.77**	**820.7**	**42.07**	**2.98**
University of Osijek	33	1.34	24.9	1.22	2.82	33	1.40	24.9	1.28	2.82
University of Rijeka	63	2.57	56.8	2.77	3.10	61	2.69	54.8	2.81	3.10
University of Split	58	2.36	50.0	2.44	2.72	58	2.46	50.0	2.56	2.72
Total other universities	**154**	**6.28**	**131.7**	**6.43**	**2.90**	**152**	**6.46**	**129.7**	**6.65**	**2.89**
Total universities	*1218*	*49.65*	*1004.8*	*49.09*	*2.97*	*1160*	*49.22*	*950.4*	*48.71*	*2.97*
Institut of Immunology	29	1.18	20.3	0.99	3.17	29	1.23	20.3	1.04	3.17
Other 11 institutes	27	1.10	18.9	0.92	2.61	26	1.10	18.4	0.94	2.50
Other institutes	**56**	**2.28**	**39.2**	**1.91**	**2.90**	**55**	**2.33**	**38.7**	**1.98**	**2.85**
Epidemiological Unit, Slav. Brod	3	0.12	1.5	0.07	1.00	3	0.13	1.5	0.08	1.00
Other 19 sanitary institutions	24	0.98	16.9	0.83	2.87	23	0.98	16.4	0.84	2.91
Total sanitary services	**27**	**1.10**	**18.4**	**0.90**	**2.65**	**26**	**1.10**	**17.9**	**0.92**	**2.68**

Table 7 (cont.)

Institution	A	% of total	B	% of total	C	D	%	E	%	F
INA	23	0.94	15.6	0.76	3.13	23	0.98	15.6	0.80	3.13
Končar	17	0.69	11.5	0.56	2.88	17	0.72	11.5	0.59	2.88
Pliva	30	1.22	18.3	0.89	3.23	30	1.28	18.3	0.94	3.23
Other 22 industrial companies	39	1.59	23.5	1.15	3.13	39	1.66	23.6	1.21	3.13
Total industr. company institut.	**109**	**4.44**	**68.9**	**3.37**	**3.12**	**109**	**4.64**	**68.9**	**3.53**	**3.12**
Hydrometeorological Institute	10	0.41	10.0	0.48	3.60	10	0.43	10.0	0.51	3.60
High Military School	7	0.29	3.8	0.34	3.57	7	0.30	3.8	0.19	3.57
Other 7 governmenal institutions	11	0.45	8.4	0.54	3.64	10	0.43	7.4	0.38	3.60
Total state administration	**28**	**1.14**	**22.2**	**1.08**	**3.61**	**27**	**1.15**	**21.2**	**1.09**	**3.59**
Croat. Acad. of Scien. and Arts	12	0.49	9.5	0.46	3.50	10	0.43	7.5	0.38	3.70
Other 3 institutions	9	0.37	8.5	0.42	3.14	8	0.34	7.5	0.38	3.00
Total other institutions	**21**	**0.86**	**18.0**	**0.88**	**3.26**	**18**	**0,77**	**15.0**	**0.77**	**3.39**
TOTAL	*2453*	*100.0*	*2047*	*100.0*	*2.87*	*2351*	*100.0*	*1951*	*100.0*	*2.86*

A = Total number of published papers.
B = Partial contribution of published papers of institution.
C and F = Average quality of journal.
D = Total number of published "pure" papers.
E = Partial contribution published "pure" papers of institution.

Table 8

Scientific subfield distribution of papers published by the most productive institutions from the Republic of Croatia

Scientific subfield	RBI	FM	FSM	IMR	IP	FT	FPB	URI	UST	Oth	Tot
Biology	25	83	7	11	-	2	2	16	2	31	178
Chemistry	69	-	27	-	-	1	5	1	5	25	132
Physics of Condensed Matter	22	-	37	-	51	1	-	3	-	6	120
Physical Chemistry	64	1	17	-	9	5	1	3	1	6	106
Pharmacology & Pharmacy	8	20	5	7	-	2	24	-	-	19	88
Analytical Chemistry	30	2	7	4	-	5	5	3	-	16	76
Physics	38	-	18	-	13	2	-	1	1	3	76
Nuclear Physics	32	-	24	-	1	3	-	-	4	5	66
Anthropology	-	15	-	21	-	-	-	-	-	18	54
Biochemistry & Molec. Biology	28	10	2	3	-	-	3	1	-	6	53
Organic Chemistry	23	-	10	-	-	7	2	-	-	11	53
Environmental Sciences	19	1	3	10	-	2	-	2	3	8	48
Applied Physics	27	1	6	-	11	-	-	1	-	2	48
Chrystallography	18	1	21	-	1	2	-	-	-	3	46
Instruments & Instrumentation	33	-	1	-	2	-	-	-	-	9	45
Radiology & Nuclear Medicine	6	23	1	2	-	-	3	-	5	3	43
Polymer Science	20	-	4	-	-	17	-	-	-	20	61
Oceanography	27	-	3	1	-	-	-	-	3	10	44
Oncology	13	24	-	1	-	-	-	-	-	4	42
Immunology	7	25	1	-	-	-	-	4	-	5	42
Inorganic & Nuclear Chemistry	17	-	9	10	-	1	3	-	-	2	42
Genetics & Heredity	6	5	5	11	-	-	-	-	1	10	38
Atomic, Molec. & Chem. Physics	19	-	2	-	14	1	-	-	-	-	36
Electrochemistry	19	-	-	-	1	7	-	-	3	5	35

Table 8 (cont.)

Scientific subfield	RBI	FM	FSM	IMR	IP	FT	FPB	URI	UST	Oth	Tot
Materials Science	15	-	12	-	4	3	-	-	-	9	43
General & Internal Medicine	-	18	-	7	-	-	-	2	1	8	36
Food Science & Technology	3	4	-	5	-	-	7	-	-	14	33
Public Health	1	10	-	14	-	-	-	-	3	3	31
Neurosciences	6	16	-	-	-	-	1	2	-	5	30
Astronomy & Astrophysics	-	-	-	-	1	1	-	1	-	26	29
Obstetrics & Gynecology	-	24	-	-	-	-	-	4	-	1	29
Geosciences	13	-	2	-	-	-	-	-	-	8	23
Arts & Humanities	-	-	-	-	-	-	-	-	1	22	23
Hematology	2	13	4	1	-	-	-	-	-	2	22
Subtotal	610	296	228	108	108	62	56	44	34	325	1871
Other scientific subfields	121	156	31	18	8	21	8	19	23	176	583
TOTAL	731	452	261	126	116	83	64	63	57	501	2454

RBI = Ruđer Bošković Institute
FM = Faculty of Medicine
FSM = Faculty of Sciences & Mathematics
IP = Institute of Physics
IMR = Institute for Medical Research & Occupational Health
FT = Faculty of Technology
URI = University of Rijeka
UST = University of Split
FPB = Faculty of Pharmacy & Biochemistry
Oth = All other institution
Tot = Total

Conclusion

1. Researchers from the Republic of Croatia, in the period 1990-1992, published 2047 papers, covered by Source Indexes of *SCI, SSCI,* and *A&HCI,* with addresses of institutions from Croatia. Most of the published papers (1912) is covered by *SCI,* and this output 17.5% higher than can be expected on the base of Croatian contribution in the world population (0.09%).
2. Expenditure of researcher from Croatia are approx. 15% of the world average, and consequently a prise of ISI covered paper was 24% of the world average.
3. Contribution of articles in total croatian output is higher than it is in the world output, while contribution of meeting abstracts and editorials is significantly lower.
4. Average number of authors per published paper is slightly higher (3.57) than world average (3.26).
5. Approx. 12% of papers are published in four domestic journals, whereas other papers are published in more than 700 different international journals.
6. Researchers (less than 20% of total number) working in major fields of *Chemical* and *Physical Sciences* have a productivity per research-year multiply higher than others, contributing with 45% of total scientific output of Croatia.
7. The first five most productive institutions Ruder Bošković Institute, the Faculty of Medicine, the Faculty of Sciences & Mathematics, Institute of Physics, and Institute of Medical Research and Occupational Health, produce over 70% of the total number of croatian publications. The quality of the used journals is higher than in the case of other institutions.

*

Thanks are due to Mr *Zvonko Bencetić* for sotware and hardware help during preparation of manuscript.

References

1. A. SCHUBERT, W. GLÄNZEL, T. BRAUN, Scientometric datafiles. A comprehensive set of indicators on 2649 journals and 96 countries in all major science fields and subfields 1981-1985, *Scientometrics,* 16 (1989) 3-478.

2. S. ARUNACHALAM, K. C. GARG, A small country in a world of big science: A preliminary bibliometric study of science in Singapore, *Scientometrics,* 8 (1985) 301-313.
3. A. SCHUBERT, T. BRAUN, Some scientometric measures of publishing performance for 85 Hungarian research institutes, *Scientometrics,* 3 (1981) 379-388.
4. E. GARFIELD, Third world research, Part 1. Where it is published, and how often it is cited, *Current Contents,* (33) 5-15, 15 August 1983.
5. E. GARFIELD, Third world research, Part 2. Most-cited articles discipline orientation, and research front concentration, *Current Contents,* (34) 5-15, 22 August 1983.
6. F. SAAVEDRA, M. R. MACKENZIE, R. PESSOT, M. KRAUSKOPF, Size and ageing of the scientific community in Chile, *Scientometrics,* 27 (1993) 105-117.
7. M. T. BECK, V. GÁSPÁR, Scientometric evaluation of the scientific performance at the faculty of natural sciences, Kossuth Lajos University, Debrecen, Hungary, *Scientometrics,* 20 (1991) 37-54.
8. *Measure for science* (in Croatian), Z. LACKOVIĆ, LJ. ČEČUK, Z. BUNETA, (Eds), Medicinska naklada, Zagreb, 1991.
9. Z. BUNETA, Z. LACKOVIĆ, Scientometric studies of medical sciences in Yugoslavia, *Scientia Yugoslavica,* 14 (1988) 25-36.
10. N. PRAVDIĆ, V. OLUIĆ-VUKOVIĆ, T. TOTH, Bibliometric of contribution by scientists from Croatia (Yugoslavia) in the field of chemistry: Rank-frequency distribution, *Kemija u industriji,* 31 (1982) 351-356.
11. M. PENAVA, Science Citation Index (SCI) and the reflection of papers in the field of biology published in Yugoslav journals by scientists from Croatia (in Croatian), *Acta Bot. Croat.,* 43 (1984) 375-382.
12. B. MOMČILOVIĆ, V. SIMEON, Production of scientific and technical information in the Institute for medical research and occupational health in the past decade (1968-1977) (in Croatian), *Arhiv Hig. Rada Toksikol.,* 30 (1979) 33-48.
13. B. KLAIĆ, Scientometric analysis of scientific and educational activities of chemists working at the Ruder Bošković Institute, for the period 1961-1983 (in Croatian), *Kemija u industriji,* 35 (1986) 141-149.
14. B. KLAIĆ, Scientometric analysis of the research activities of chemists from the Ruder Bošković Institute (Yugoslavia), 1976-1985, *Scientometrics,* 19 (1990) 11-24.
15. *Statistical Yearbook*, 1992, Republic of Croatia, Central bureau of statistics, Zagreb, 1993.
16. *Britannica Book of the Year*, Encyclopedia Britannica, Inc., Chicago, 1993.
17. Source Index of the *Science Citation Index,* 1990-1992, edited E. GARFIELD (Institute of Scientific Information, Philadelphia, USA).
18. Source Index of the *Social Science Citation Index,* 1990-1992, edited E. GARFIELD (Institute of Scientific Information, Philadelphia, USA).
19. Source Index of the *Arts & Humanities Citation Index,* 1990-1992, edited E. GARFIELD (Institute of Scientific Information, Philadelphia, USA).
20. *Journal Citation Reports (JCR,* Section 8), 1992, edited E. GARFIELD (Institute of Scientific Information, Philadelphia, USA).
21. *Science Citation Index Guide,* 1990-1992, edited E. GARFIELD (Institute of Scientific Information, Philadelphia, USA).
22. *Social Science Citation Index Guide,* 1990-1992, edited E. GARFIELD (Institute of Scientific Information, Philadelphia, USA).
23. Unesco, *Statistical Yearbook,* Unesco, Paris, 1993.
24. A. SCHUBERT, A. TELCS, Publication potential – an indicator of scientific strength for cross-national comparison, *Scientometrics,* 9 (1986) 231-238.
25. A. J. NEDERHOF, R. F. MEIJER, H. F. MOED, A. F. J. VAN RAAN, Research performance indicators for university departments: A study of an agricultural university, *Scientometrics,* 27 (1993) 157-178.
26. M. BONITZ, E. BRUCKNER, A. SCHARNHORST, The Science Strategy Index, *Scientometrics,* 26 (1993) 37-50.