BIBLIOMETRIC ASSESSMENT OF COUNTRY'S CONTRIBUTION TO WORLD SCIENCE.

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Lecture Outline

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2. Research activity of countries
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4. Contribution of leading countries to science
5. South Africa's contribution to Science and Social Sciences
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I. Introduction

The present study is an attempt to assess a country's contribution to world science using statistical information, mostly of bibliometric nature. There are three groups of quantitative indicators to describe innovation activity: (1) social science indicators [cost of Research & Development activity, workforce in research, etc], (2) patent statistics, and (3) bibliometric indicators [number of publications, their citedness, etc]. While the two first groups reflect the first stage of innovation process, the third group corresponds to scientific communication, the "intensity and efficiency" of fundamental and applied research, their contribution to the development of the scientific knowledge. The data were obtained from annual databases of the Thomson Scientific, USA (formerly Institute of Scientific Information), that is Science Citation Index (SCI) – for science proper, Social Sciences Citation Index (SSCI) – for social sciences, as well as National Science Indicators covering the period from 1981 to 2002. The cumulative statistical information in National Science Indicators (NSI) is based on more than 5 thousand journals in science, 1500 journals in social sciences and 1100 journals in art and humanities. The total number of publications in the database (DB)

exceeds 3 million papers. The database presents statistics on a total of 100 countries with at least 1000 publications during the 17 year period.

Bibliometric assessment was based on two principles:

1) Research activity as reflected in the number of publications and publication payload, and

2) Quality of research as reflected in citation statistics, i.e. the total number of citations of publications of the country, per cent of publications cited, and mean number of citations per publication (i.e. impact).

II. RESEARCH ACTIVITY OF COUNTRIES

According to NSI DB the period under study (that is 1993-1997) saw more than 3 million papers published with USA as world leader contributing 37.4 per cent of publications. There were 86 countries with more than 500 papers to their credit (i.e. more than 100 papers a year). Table 1 provides the top 45 countries, ranked according to the number of publication. These countries may be grouped into 7 groups with significant gaps between those groups as follows:

(1). USA - 32.4 per cent; (2) UK, Japan and Germany - 22.6 (more than 250000 papers each); (3)France, Canada, Russia, Italy - 16.1 (more than 100000 papers each); (4) Australia, Netherlands, Spain, India, Sweden, Switzerland, China - 13.2 (more than 50000 papers each); (5) Israel, Belgium, Poland, Taiwan, Denmark, Finland, Brazil, South Korea, Austria - 7.5 (more than 25000 papers each); (6) Norway, Ukraine, New Zealand, **South Africa,** Greece, Hungary, Mexico, Argentina, Czech Rep., Turkey, Hong Kong - 4.5 (more than 12000 papers each); (7) Egypt, Ireland, Singapore, Portugal, Slovakia, Bulgaria, Chile, Saudi Arabia, Romania, Belarus - 2.0 (more than 5000 papers each). The other countries, numbering 41, contributed 1.7 per cent of the total.

Table 1: Bibliometric Indicators of Research Activities of Countries, 1993-1997: (N = 3 856 085)

	Number of publications	**% of world total**
1) Group		**32.4**
1. USA	1 249 520	
2) Group >250 000 papers		**22.6**
2. UK	309 725	
3. JAPAN	290 582	
4. GERMANY	269 588	
3) Group >100 000 papers		**16.1**
5. FRANCE	205 826	

6. CANADA	168 069	
7. RUSSIA	123 281	
8. ITALY	123 062	
4) Group >50 000 papers		**13.2**
9. AUSTRALIA	89 622	
10. NETHERLANDS	83 514	
11. SPAIN	79 047	
12. INDIA	73 267	
13. SWEDEN	63 904	
14. SWITZERLAND	57 822	
15. CHINA	57 135	
5) Group >25 000 papers		**7.5**
16. ISRAEL	41 789	
17. BELGIUM	40 277	
18. POLAND	33 903	
19. TAIWAN	32 583	
20. DENMARK	31 868	
21. FINLAND	28 710	
22. BRAZIL	27 652	
23.SOUTH KOREA	26 689	
24. AUSTRIA	26 235	
6) Group >12 000 papers		**4.5**
25. NORWAY	20 701	
26. UKRAINE	18 138	
27. NEW ZEALAND	17 961	
28. SOUTH AFRICA	**17 429**	
29. GREECE	16 474	
30. HUNGARY	15 155	
31. MEXICO	14 644	
32. ARGENTINA	13 687	
33. CZECH Rep	13 674	
34. TURKEY	12 816	
35. HONG KONG	12 526	
7) Group >5 000 papers		**2.0**

36. EGYPT	9 999
37. IRELAND	9 882
38. SINGAPORE	9 006
39. PORTUGAL	8 107
40. SLOVAKIA	7 715
41. BULGARIA	7 524
42. CHILE	6 986
43. SAUDI ARABIA	6 931
44. ROMANIA	6 114
45. BYELARUS	5 232

Table 2 provides the rank distribution of the countries according to the publications per 1000 inhabitants. [NB: there are countries with population of more than 1 million].

Table 2: Number of Publication per 1000 Inhabitants (1993-1997)

I.	**Country**	**Publications per 1000 inhabitants**
1.	SWITZERLAND	8.14
2.	SWEDEN	7.52
3.	ISRAEL	7.21
4.	DENMARK	6.01
5.	FINLAND	5.61
6.	CANADA	5.60
7.	NETHERLANDS	5.35
8.	UK	5.25
9.	NEW ZEALAND	4.99
10.	AUSTRALIA	4.82
11.	NORWAY	4.70
12.	USA	4.66
II.		
13.	BELGIUM	3.95
14.	FRANCE	3.51
15.	GERMANY	3.28

16. AUSTRIA	3.24
17. IRELAND	2.76
18. SINGAPORE	2.59
19. JAPAN	2.30
20. HONG KONG	2.16
21. ITALY	2.14
22. SPAIN	2.01
23. SLOVENIA	1.85
III.	
24. GREECE	1.57
25. TAIWAN	1.51
26. HUNGARY	1.49
27. SLOVAKIA	1.43
28. CZECH REPUBLIC	1.32
29. ESTONIA	1.27
IV.	
30. KUWAIT	0.96
31. BULGARIA	0.91
32. CROATIA	0.91
33. POLAND	0.88
34. RUSSIA	0.84
35. PORTUGAL	0.82
36. SAUDI ARABIA	0.77
V.	
37. SOUTH KOREA	0.59
38. LATVIA	0.57
39. BYELARUS	0.51
40. UNITED EMIRATES	0.49
41. CHILE	0.48
42. COLUMBIA	0.42
43. SOUTH AFRICA	**0.41**

44. LITHUANIA	0.39
45. ARGENTINA	0.38
44. YUGOSLAVIA	0.38
47. UKRAINE	0.36
48. ARMENIA	0.33
49. TRINIDAD & TOBAGO	0.33
50. JORDAN	0.31
51. VENEZUELA	0.30
52. COSTA RICA	0.28
53. URUGUAY	0.28
54. JAMAICA	0.27
55. ROMANIA	0.27

VI.

56. TURKEY	0.20
57. BRAZIL	0.17
58. GEORGIA	0.17
59. TUNISIA	**0.17**
60. EGYPT	**0.15**
61. LEBANON	0.15
62. MEXICO	0.15
63. CUBA	0.14
64. PANAMA	0.14
65. AZERBAIJAN	0.13
66. MALAYSIA	0.13

VII.

67. PAPUA N GUINEA	0.10
68. ZIMBABWE	**0.10**
69. KENYA	**0.09**
70. MOROCCO	**0.09**
71. INDIA	0.08
72. KAZAKHSTAN	0.07
73. PAKISTAN	0.07

74. UZBEKISTAN	0.07
75. CAMEROON	0.06
76. THAILAND	0.06
77. PEOPLES R CHINA	0.05
78. ALGERIA	**0.04**
79. NIGERIA	**0.04**
80. IVORY COAST	**0.03**
81. IRAN	0.03
82. GHANA	**0.03**
83. PERU	0.03
84. SRI LANKA	0.03
85. TANZANIA	**0.03**
86. ZAMBIA	**0.03**
87. IRAQ	0.02
88. PAKISTAN	0.02
89. PHILIPPINES	0.02
90. SENEGAL	**0.02**
91. ETHIOPIA	**0.016**
92. SUDAN	**0.016**
93. BANGLADESH	0.013
94. VIETNAM	0.012
95. INDONESIA	0.007

The visible gaps between the groups lie around the values of **4, 1.8, 1.2, 0.7, 0.25, and 0.12** of the number of papers per 1000 inhabitants. The first group includes North America, Oceania, Northern Europe, Switzerland and Israel (12 countries), followed by the rest of Western Europe (and rather unexpectedly - Slovenia) and three countries of the Far East: Japan, Singapore and Hong Kong (11 countries). Groups III (6 countries) and IV (7 countries) include Eastern Europe, Taiwan and two Near East countries - Kuwait and Saudi Arabia. Russia is ranked 34^{th}. Groups V (19 countries) and VI (11 countries) include seven republics of the former USSR, Yugoslavia, Romania, 12 countries of Latin America, five Arab countries, Turkey, Malaysia, South Korea and South Africa. The last group includes mostly African and Asian countries, among them such major contributors to world science as India and China.

To a great extent the value of the number of publications per 1000 inhabitants is dependent on per capita gross domestic product (GDP). The correlation of the two measures is reflected in average (non-weighted) values of the above mentioned groups:

Table 3: Correlation between no. of publications per 1000 inhabitants and per capita GDP

	No. of publications per 1000 inhabitants	**Per capita GDP** (Thousands of USD)
1st group	5.82	21.5
2d group	2.71	19.2
3d group	1.45	10.0
4th group	0.87	9.2
5th group	0.39	6.9
6th group	0.15	4.0
7th group	0.045	2.3

It is quite clear that correlation is not linear, i.e. the GDP average of the first group is 10 times greater than the average of the 7th group, while the corresponding difference in publications is 130 times.

If we introduce another indicator of research activity - **publication payload** (per million dollars) which is **the number of publications of a country divided by GDP, the pattern of productivity for** the four leading groups will be as follows:

Table 4: Bibliometrics Indicators for 4 groups of countries: Correlation between no. of publications per 1000 inhabitants and publications payload per million dollars

	Number of publications/1000 inhabitants	**Publications payload**
I.		
1. SWITZERLAND	8.14	0.35
2. SWEDEN	7.52	0.36
3. ISRAEL	7.21	0.45
4. DENMARK	6.01	0.26
5. FINLAND	5.61	0.30
6. CANADA	5.60	0.24
7. NETHERLANDS	5.35	0.25
8. UK	5.25	0.26
9. NEW ZEALAND	4.99	0.28

10. AUSTRALIA	4.82	0.23
11. NORWAY	4.70	0.18
12. USA	4.66	0.17
II.		
13. BELGIUM	3.95	0.19
14. FRANCE	3.51	0.16
15. GERMANY	3.28	0.17
16. AUSTRIA	3.24	0.15
17. IRELAND	2.76	0.15
18. SINGAPORE	2.59	0.08
19. JAPAN	2.30	0.097
20. HONG KONG	2.16	-
21. ITALY	2.14	0.10
22. SPAIN	2.01	0.13
23. SLOVENIA	1.85	0.18
III.		
24. GREECE	1.57	0.13
25. TAIWAN	1.51	0.08
26. HUNGARY	1.49	0.20
27. SLOVAKIA	1.43	0.27
28. CZECH REPUBLIC	1.32	0.14
29. ESTONIA	1.27	0.19
IV.		
30. KUWAIT	0.96	0.04
31. BULGARIA	0.91	0.24
32. CROATIA	0.91	0.23
33. POLAND	0.88	0.13
34. RUSSIA	0.84	0.18
35. PORTUGAL	0.82	0.06
36. SAUDI ARABIA	0.77	0.07

Pay special attention to the difference in the publication payload between Russia and USA on the one hand and that of Japan on the other. Perhaps, the case of Japan is due to the fact that many publications in Japanese are not included in the database.

For each of the seven groups, we can cite examples of countries whose publication payload is greater than what might be expected from group average. The two columns below show countries with higher and lower publication payload as compared to the group average:

Table 5: Countries' publications payload

	Higher	**Lower**
1st group	Israel, Sweden, Switzerland	Norway, USA
2d group	Belgium, Slovenia	Italy, Japan, Singapore
3d group	Slovakia, Hungary, Estonia	Taiwan,
4th group	Bulgaria, Croatia, Russia	Saudi Arabia, Portugal
5th group	Latvia, Belarus, Lithuania, Armedia	Chile, Argentina, Jordan, Venezuela, Uruguay
6th group	Georgia, Azerbaijan	Turkey, Brazil, Mexico,
7th group	Zimbabwe, Kenya, India	Thailand, Peru, Sri Lanka, Pakistan, Indonesia

The groupings may be interpreted as follows. Let's take for example the first group. The number of publications on one million dollars of gross domestic product (GDP) in Israel, Sweden or Switzerland is twice as many publications as compared to Norway or USA. The geographic difference between the two columns is highly significant. There are 8 republics of the former USSR and 5 countries of Eastern Europe in the left column. On the other hand, there are 7 Latin American countries and 4 Middle East countries in the right column. The data reveals that the tradition of scientific research (a kind of 'research inertia') in the former USSR and communist countries of Eastern Europe is flourishing despite the sharp decline of financial support. The same inertia (but with opposite sign) is evident in rapidly developing countries of Far East, Southern Europe, Middle East and Latin America. Here, the growing economies are not yet reflected in the proportional growth of publications. Of course, the number of publications is constantly increasing, but due to the historic 'research backwardness' it is not proportional to the increase in wealth.
This pattern may be clearly seen in the following figures:

Table 6: Number of publications vs total sum of GDPs

	Total Sum of GDPs (Billions of USD)	**Publications (In thousands)**
Former USSR (15 countries)	1100	160
Poland, Czech Rep., Slovakia, Hungary, Romania, Slovenia, Croatia, Yugoslavia, Bulgaria	650	96
Japan, South Korea, Taiwan, Singapore	4100	360
Portugal, Spain, Italy, Greece, Turkey	2500	240
Mexico, Cuba, Columbia, Venezuela, Peru, Chile, Argentina, Uruguay, Brazil	2900	70
Morocco, Algeria, Tunisia, Egypt, Jordan,Lebanon,Saudi Arabia, Kuwait, Un.Arab Emirates, Iraq, Iran	900	30

II. CITATION STATISTICS

The journals indexed in ISI databases are carefully selected. They have good reputations in academic community and accordingly are often cited. The cited papers constitute 59.87 per cent of all papers in the NSI database and the leading research countries (group 1 and 2 of Table 2) vary around that figure as illustrated in Table 7.

Table 7a: Citation contributions of leading research countries

Country	***%***
Denmark	69.2
Switzerland	68.4
Netherlands	68.0
Sweden	67.8
USA	66.0
Belgium	65.1
UK	65.0
Canada	64.0
Germany	64.0
Italy	63.0
Australia	63.0
France	62.8
Israel	61.7
Japan	60.2

However the corresponding figure for African countries (with more than 800 publications) is lower:

Table 7a: Citation contributions of leading research African countries

Country	***%***
Kenya	55.2
Tanzania	53.9
South Africa	53.8
Zimbabwe	52.2
Senegal	51.66
Cameroon	51.18
Ghana	50.12

Impact is defined as ‘the ratio of number of citations to number of publications’. The measure is effective as a tool of differentiation of both single authors’ and organizations’ or countries’ scientific influence (see Table 4 Impact of individual countries).

Table 8: Impact of individual countries (with more than 2000 publications)

Rank	Country	Impact
1	Switzerland	5.90
2	US	5.19
3	Denmark	4.62
4	Netherlands	4.61
5	Sweden	4.53
6	UK	4.32
7	Finland	4.16
8	Belgium	4.13
9	Canada	3.99
10	Germany	3.97
11	France	3.80
12	Italy	3.60
13	Austria	3.59
14	Israel	3.56
15	Norway	3.39
16	Australia	3.37
17	Japan	3.20
18	New Zealand	3.00
19	Spain	2.88
20	Ireland	2.82
21	Hungary	2.60
22	Thailand	2.47
23	**Kenya**	**2.42**
24	Portugal	2.42
25	Venezuela	2.38
26	Chile	2.28
27	Malaysia	2.24
28	Slovenia	2.15
29	Greece	2.12
30	Poland	2.10

31	Argentina	2.06
32	**South Africa**	**2.02**
33	Brazil	2.00
34	Hong Kong	1.97
35	Mexico	1.95
36	Croatia	1.87
37	Singapore	1.81
38	Taiwan	1.72
39	South Korea	1.63
40	Czech Rep.	1.55
41	Bulgaria	1.49
42	Yugoslavia	1.41
43	China	1.36
44	Romania	1.29
45	Russia	1.29
46	India	1.23
47	Turkey	1.20
48	**Morocco**	**1.15**
49	Iran	1.14
50	Slovakia	1.13
51	Saudi Arabia	1.13
52	Pakistan	1.01
53	**Egypt**	**0.97**
54	Ukraine	0.92
55	**Nigeria**	**0.89**
56	Byelarus	0.81

The ranked list of countries (table 8) is similar to that of Table 2. The most significant differences among leading research countries are United States and Italy with higher impact factor, and Israel, Hong Kong, Singapore and Russia, which recorded lower impact factors. On the other hand some tropical countries show magnificent impact as compared to per capita publications. These include Thailand (2.47), Kenya (2.42), Malaysia (2.24), Venezuela (2.38), and South Africa (2.02). This pattern could be attributed to some popular papers in biology, plant and animal science and medicine.

III CONTRIBUTION OF LEADING COUNTRIES TO SCIENCE

The contribution of individual countries varies significantly in major fields of world science. Those leading countries cover the field of astrophysics, more than 90 per cent of molecular biology and genetics, more than 80 per cent of geosciences, biology and biochemistry, neurosciences, immunology. It is only in agricultural sciences that it falls short of 70 per cent of world total.

While the US, the UK, Germany, France and Canada show only slight variation in their respective contributions to 18 fields of science, Japan's contribution is relatively significant in physics, chemistry, materials science and such applied fields as pharmacology and agricultural science. Its contribution to geosciences and ecology is low, but still exceeds 3 per cent. Russia differs from all other countries by its spectrum of major fields. The country shows marked preference for physics and astrophysics, chemistry and geosciences, where her contribution is 2 or 3 times greater than her average contribution. On the other hand her contribution to biosciences is 2 or 3 times less while its contribution to medicine and pharmacology is 5-10 times less than average. Russian contribution is very significant in such narrow fields as metallurgy (more then 13%), inorganic chemistry (10.0%), nuclear engineering (9.7%), optics and acoustics (9.4%), physical chemistry (9.0%), applied physics (8.7%), instrumentation (8.5%), space science (6.9%), artificial intelligence (6.6%), spectroscopy (6.6%). The level of impact of Russian papers is relatively low although it approaches the world average in mathematics and (rather unexpectedly) in pharmacology. Table 9 shows that Russia is ranked 7th in period 1993-97. It should however be born in mind that in 1984 USSR ranked second and since then the relative importance of Russian contribution to world science has been declining. In 1998-2002 Russia ceded its 7th rank to Italy while Russia ceded its 8 rank to China [See Table 9]. In 2004 Russia ranked 9th.

Table 9: Country ranking, 1981-2002

Rank 98-02	Rank 93-97	COUNTRY	1993 - 1997		1998-2002	
			%	Number of papers	%	Number of papers
1	1	USA	37.17	1 207 230	34.17	1 229 994
2	3	JAPAN	8.90	288 941	9.55	343 733
3	2	UK	9.24	300 242	9.30	334 676
4	4	GERMANY	8.08	262 482	8.82	317 370
5	5	FRANCE	6.12	198 983	6.34	228 185
6	6	CANADA	5.00	162 409	4.48	161 338
7	8	ITALY	3.73	121 007	4.18	150 417
8	***15***	***CHINA !!+***	***2.10***	***68 320***	***3.63***	***130 633***
9	***7***	***RUSSIA***	***3.71***	***120 401***	***3.37***	***121 318***
10	11	SPAIN	2.38	77 203	2.95	106 115
11	9	AUSTRALIA	2.69	87 496	2.86	103 036
12	10	NETHERLANDS	2.53	82 330	2.52	92 220
13	12	INDIA	2.23	72 541	2.23	80 146
14	13	SWEDEN	1.95	63 355	2.05	73 644
15	14	SWITZERLAND	1.75	56 966	1.85	66 772
16	***23***	***SOUTH KOREA+***	***0.82***	***26 752***	***1.76***	***63 452***
17	17	BELGIUM	1.21	39 379	1.35	48 572
18	***19***	***TAIWAN !+***	***1.00***	***32 520***	***1.34***	***48 269***
19	***22***	***BRAZIL !+***	***0.85***	***27 639***	***1.34***	***48 239***
20	16	ISRAEL	1.25	40 476	1.26	45 433
21	18	POLAND	1.06	34 386	1.26	45 325
22	20	DENMARK	0.97	31 514	1.04	37 607
23	21	FINLAND	0.88	28 482	0.98	35 259
24	24	AUSTRIA	0.79	25 554	0.95	34 156
25	***34***	***TURKEY !+***	***0.39***	***12 586***	***0.76***	***27 406***
26	25	NORWAY	0.63	20 378	0.67	24 095
27	29	GREECE	0.50	16 254	0.66	23 668
28	31	MEXICO	0.45	14 486	0.64	23 202
29	27	NEW ZEALAND	0.54	17 488	0.59	21 205
30	32	ARGENTINA	0.42	13 540	0.57	20 538
31	33	CZECH REPUBL	0.42	13 617	0.57	20 398
32	30	HUNGARY	0.46	14 901	0.52	18 874
33	**28**	**SOUTH AFRICA**	**0.52**	**16 877**	**0.50**	**18 152**
34	26	UKRAINE	0.56	18 325	0.50	18 031
35	38	SINGAPORE	0.28	8 944	0.48	17 269
36	39	PORTUGAL	0.25	7 979	0.42	15 008
37	37	IRELAND	0.29	9 531	0.36	12 975
38	**36**	**EGYPT**	**0.31**	**10 024**	**0.31**	**11 178**
39	42	CHILI	0.21	6 890	0.26	9 226
40	40	SLOVAKIA	0.23	7 462	0.25	9 102
41	44	POMANIA	0.19	6 063	0.23	8 237

Database - National Science Indicators: Standard 1981-2002; 1993-1997: total number of publication 3248146; 1998-2002: total number of publication 3599665

IV. SOUTH AFRICA CONTRIBUTION TO SCIENCE AND SOCIAL SCIENCES

South Africa is ranked 28th, in the period 1993-97. In the next 5-year period, South Africa is ranked 33rd. The research activity of South Africa grew by 1275 publications (or 7.7%) between the two year periods. With regard to other African countries, Egypt is ranked 38th with 11 178 publication in the period 1998-02.

Table 10 provides the research activity of 47 African countries that are included in the NSI database. The contribution of all these countries is slightly more than 1.43 % of the world science.

Table 10: Contribution of African countries, 1998-2002 (N = 3 599 665)

Rank	*Country*	*%*	*papers*
33	**SOUTH AFRICA**	**0.50**	**18152**
38	EGYPT	0.31	11178
56	NIGERIA	0.10	3621
58	TUNISIA	0.08	2720
60	**KENYA**	**0.07**	**2639**
66	ALGERIA	0.06	1993
78	ZIMBABWE	0.03	1119
80	TANZANIA	0.03	1079
81	ETHIOPIA	0.03	1042
83	CAMEROON	0.03	934
86	GHANA	0.02	816
87	SENEGAL	0.02	815
90	UGANDA	0.02	777
93	IVORY COAST	0.02	671
99	BOTSWANA	0.01	494
100	MALAWI	0.01	485
104	SUDAN	0.01	439
106	ZAMBIA	0.01	378
107	BURKINA FASO	0.01	378
110	GAMBIA	0.01	344
113	BENIN	0.01	298
116	GABON	0.01	282
118	LIBYA	0.01	240
119	NIGER	0.01	238
120	REUNION	0.01	229
121	NAMIBIA	0.01	227
126	MALI	0.01	210
127	MAURITIUS	0.01	197
141	MOZAMBIQUE	0.00	167
143	CONGO PEOPL REP	0.00	156
146	TOGO	0.00	136
153	CONGO DEM REP	0.00	89
158	GUINEA BISSAU	0.00	72
160	CENT AFR REPUBL	0.00	61

161	SWAZILAND	0.00	59
162	MAURITANIA	0.00	59
163	ANGOLA	0.00	55
165	GUINEA	0.00	49
167	RWANDA	0.00	45
171	SEYCHELLES	0.00	40
173	BURUNDI	0.00	36
174	SIERRA LEONE	0.00	36
175	LESOTHO	0.00	35
177	LIBERIA	0.00	9
178	SOMALIA	0.00	3

The main contributors are South Africa and Egypt with a combined research activity of more than 29 thousand publications. Research productivity of African countries (without these two countries) totals 16609 publications. It is interesting to note that 38.4% of these publications belong to the fields of science: Agricultural science (about 11%), Geosciences (4%) and Plant and animal sciences (23.4). Table 11 shows the dynamics of research activity of African countries in the period from 1988 to 2002

Table 11: Research activity of African countries, 988-2002

	Total papers NSI	Agricultural science	Geosciences	Plant & animal science
1988-92	15 103	1 632	570	3 240
1993-97	15 835	1 650	498	3 677
1998-2002	16 609	1 809	670	3 899

South Africa's contribution in these three subject domains was as follows: Agricultural science (446), Geosciences (1156), Plant & animal science (3530). Let us compare the total contributions of Ethiopia, Kenya and South Africa.

Table 12: Scientific contribution of South Africa, Kenya and Ethiopia in 24 fields of science and social science, 1998-2002

	South-Africa 18 152 papers				**Kenya 2639 (0.07%)**				**Ethiopia 1043 (0.03**		
	Papers	Field %	Country %	% cited papers	Papers	Field %	Country %	% cited papers	Papers	Field %	Co %
Agricultural Sciences	446	0.53	2.46	54.49	260	0.31	9.85	50	**125**	**0.15**	**12.**
Biology & Biochemistry	979	0.36	5.39	65.37	99	0.04	3.75	69.7	31	0.01	2.9
Chemistry	**1663**	**0.33**	**9.16**	57.61	38	0.01	1.44	42.12	37	0.01	3.5
Clinical Medicine	**3836**	**0.44**	**21.13**	58.00	**759**	**0.09**	**28.76**	64.03	**384**	**0.04**	**36.**
Computer Science	104	0.24	0.57	33.66	0	0	0	-	0	0	0
Ecology/Environment	1070	1.16	5.89	52.99	**266**	**0.29**	**10.08**	52.63	4.9	0.05	4.7

Economics & Business	235	0.24	1.29	27.66	35	0.07	1.33	51.44	17	0.03	1.6
Education	106	0.80	0.58	25.48	4	0.03	0.15	50.0	1	0.01	0.1
Engineering	853	0.32	4.70	40.45	60	0.02	2.27	21.68	14	0.01	1.3
Geosciences	**1156**	**1.13**	**6.37**	51.73	59	0.06	2.24	54.25	**59**	**0.06**	**5.6**
Immunology	271	0.43	1.49	77.12	**201**	**0.32**	**7.62**	77.12	**54**	**0.08**	**5.1**
Law	6	0.06	0.03	33.44	1	0.01	0.04	-	0	0	0
Materials Science	411	0.30	2.26	49.39	8	0.01	0.30	25.0	6	0	0.5
Mathematics	265	0.41	1.46	41.51	0	0	0	-	2	0	0.1
Microbiology	518	0.64	2.85	74.32	122	0.15	4.62	76.23	36	0.04	3.4
Molecular Biology & Genetics	303	0.28	1.67	71.95	53	0.05	2.01	73.59	15	0.01	1.4
Multidisciplinary	607	1.22	3.34	48.11	67	0.13	2.54	14.94	4	0.01	0.3
Neurosciences & Behavior	263	0.19	1.45	69.58	13	0.01	0.49	69.25	18	0.01	1.7
Pharmacology	339	0.44	1.87	64.60	40	0.05	1.52	50.0	14	0.02	1.3
Physics	**1156**	**0.26**	**6.37**	57.09	27	0.01	1.02	22.25	19	0	1.8
Plant & Animal Science	**3530**	**1.59**	**19.45**	50.26	**672**	**0.30**	**25.46**	50.15	**234**	**0.11**	**22.**
Psychology/Psychiatry	482	0.49	2.66	44.81	14	0.01	0.53	37.76	23	0.02	2.2
Social Sciences general	788	0.61	4.34	43.40	**171**	**0.13**	**6.48**	49.71	35	0.03	3.3
Space Science	407	0.91	2.24	78.62	0	0	0	-	1	0.0	0.1

What follows is the ranking of South Africa amongst 170 countries in 17 fields of science.

Rank	Field of science
20	Plant & Animal Science
23	Geosciences
24	Ecology/Environment
28	Microbiology
	Space Science
29	Clinical Medicine
	Immunology
31	Pharmacology
36	Computer Science
	Molecular Biology & Genetics
38	Agricultural Sciences
	Biology & Biochemistry
39	Engineering
40	Materials Science
41	Chemistry
	Mathematics
	Physics

Table 13 ranks 18 South Africa journals from 16 field of Science as indexed in the NSI database. Seven journals from this list belong to Plant & Animal sciences. You can see that in this field, South Africa is ranked 20th.

Table 13: South Africa Scientific journals

Rank	ISI Abbr.	Journal	Field	Ip	K
1	Afr J Mar Sci	African Journal of Marine Science	Marine & Freshwater Biology Ig=2.4	1.184	**49.33**
2	S Afr J Geol	South African Journal of Geology	Geology Ig=2.69	1.021	**37.95**
3	S Afr J Marine Sci	South African Journal of Marine Science-Suid-Afrikaanse Tydskrif Vir Seewet	Marine & Freshwater Biology Ig=2.4	0.892	**37.17**
4	Water Sa	Water SA	Water Resources Ig=1.70	0.600	**35.29**
5	Onderstepoort J Vet	Onderstepoort Journal of Veterinary Research	Veterinary Science Ig=2.36	0.548	**23.22**
6	Afr Entomol	African Entomology	Entomology Ig=2.61	0.577	**22.1**
7	Ostrich	Ostrich	Ornithology Ig=1.35	0.187	**13.85**
8	Afr Zool	African Zoology	Zoology Ig=3.05	0.393	**12.9**
9	J S Afr Vet Assoc	Journal of the South African Veterinary Association-Tydskrif Van Die Suid-A	Veterinary Science Ig= 2.36	0.265	**11.23**
10	S Afr J Anim Sci	South African Journal of Animal Science	Agriculture, Dairy & Animal Science Ig=1.84	0.143	**7.90**
11	S Afr J Wildl Res	South African Journal of Wildlife Research	Ecology Ig=6.2 Zoology Ig=3.05	0.341	**7.4**
12	S Afr J Sci	South African Journal of Science	Multidisciplinary Science Ig=17.71	0.930	**5.25**
13	Samj S Afr Med J	Samj South African Medical Journal	Medicine, General & Internal Ig=22.29	0.989	**4.44**
14	S Afr J Bot	South African Journal of Botany	Plant Science Ig=11.03	0.462	**4.19**
15	J S Afr I Min Metall	Journal of the South African Institute of Mining and Metallurgy	Metall & Metal Engineering Ig=2.06 Mining & Miner Proc Ig=1.08	0.061	**3.9**
16	S Afr J Chem-S-Afr T	South African Journal of Chemistry-Suid-Afrikaanse Tydskrif Vir Chemie	Chemistry, Multidisciplinary Ig=7.83	0.240	**3.1**
17	Bothalia	Bothalia	Plant Science Ig=11.03	0.281	**2.55**
18	S Afr J Surg	South African Journal of Surgery	Surgery Ig=4.72	0.119	**2.52**

CONCLUSION

The development of science was and will be the focus of attention of researchers, science administrators, sociologists and politicians. The classification of single countries according to their contribution to world science depends mostly on two factors: 1) specific features of a particular field of science and 2) economic and scientific status of the country. Little bibliometric variations due to other factors does not seem significant.

The analysis of the National Science Indicators database gives support for the formulation of the following conclusions.

1. Nations with a well-established system of science (leading developed countries) show NORMAL development of science with a stable rate of publication growth. The contribution of the USA, Japan, Germany, the UK, France and Canada (in that order) is very significant in all fields of science. Russia's contribution was significant in physics, astrophysics, chemistry, molecular biology and genetics, materials science, engineering, geo-sciences. During the entire period under analysis the USSR as a whole (and Russia, in particular) belonged to the club of the above-mentioned leaders of world science. The countries in this list developed with the same speed in the course of the period under observation. The same is true of lesser countries of Northern and Central Europe, Australia and Israel.

China's contribution was significant in materials science – 4th ranked after the USA, Japan and Germany, mathematics (5th rank), physics (6th rank), chemistry (7th rank). In the computer science the contribution of China (4.2%) is more than 4 times when compared with Russia.

Dramatic change was observed outside this region. Italy showed one of the most dynamic progresses, especially in the fields of pharmacology, biology and biochemistry and others (see later on). Mediterranean countries developed at an accelerated pace with Spain approaching the normal European level. The first scientific fruits of Cultural Revolution were apparent in the Far East- in China proper, Taiwan, Hong Kong, Singapore and South Korea. First steps in the development of science were observed in Saudi Arabia. The progress of science in most developing counties was limited to particular applied fields (such as agricultural sciences) or to life sciences that are associated with tropical environment (plant and animal sciences, immunology, and pharmacology).

This general picture is complemented by some nations whose contribution is significant in a narrower range of fields. Italy and India performed well in the fields of **physics** and **astrophysics** while research in

chemistry was highest in India, Italy, Spain and Poland; Italy, India, Netherlands, Israel and Australia performed well in **computer science**. Other contributions were as follows: **materials science** in which India's contribution was equal to that of France or Canada with Sweden, China, Australia and Italy contributing substantially. In **geosciences,** we find two countries joining the club of world leaders, i.e. Australia and India.

In a cluster of 'new biology' (**biology and biochemistry, molecular biology and genetics, neurosciences**) we find (besides the 7 leaders) Italy, Netherlands, Australia, and Sweden. In the 90s the club was joined by newcomers: Spain, Switzerland, Belgium, Brazil, India and Israel. In the cluster of 'old biology' (**plant and animal sciences**) the list of significant contributors is very wide. It includes India, Australia, Netherlands, South Africa, Germany, Italy, Spain, Sweden, Belgium, Switzerland, Poland, Norway, Denmark, Finland, Israel, New Zealand and ,Brazil.

The significant contributors to the remaining life sciences (**clinical medicine, immunology, pharmacology**) are Italy, Sweden, Australia and Netherlands. In field of ecology are Australia, India, Sweden and Netherlands, in **engineering** - India, Italy, Australia, Netherlands, China. In **agricultural sciences** among the world leader's stable growth is observed in Japan, France and Canada. Significant contribution is supplied by India and (ever-growing) Spain.

2. The impact of political, social and economic changes was felt by science in some countries. Science in Lebanon, Armenia, Azerbaijan, Iran, Iraq, Kuwait, and Afghanistan suffered much in civil wars or wars with neighbors. (In the mid-eighties Afghanistan disappeared from the list of 160 nations, whose publications are registered by ISI). Overall stagnation of European communist countries manifested itself in scientific research as well: the decade under analysis showed 27% growth in Poland, 11% growth in Czechoslovakia, 2% growth in Hungary, 1% decline in Russia and 16% decline in Rumania.

3. An important factor in the scientific activity of a nation is its organizational and education infrastructure which is well established in North and Central Europe, North America, Australia, Israel and Japan. Similar infrastructure is typical of Eastern Europe, Russia, China, and South Africa. The modernization of this infrastructure in preceding decades (1950-70s) bore fruit in the 1980s in European Mediterranean nations. For instance, from 1981-85 to 1998-02 scientific publication activity grew by 67% in Italy, by 100% in Greece, by 132% in Spain, by 233% in Turkey (cf. corresponding figures: France 38%, Germany 26%, the UK 23%, the USA 27%) and of the North European nations, only the Netherlands approached such rate of growth (60%).

4. Analysis of scientific publishing activities revealed the following definite tendencies:

4.1. **In Europe,** (a) Italy made a spurt, especially in pharmacology, biology, astrophysics, physics, mathematics, chemistry; (b) Spain approached leading world countries in the number of publications (it was ranked 15th in 1981-85, 11th in 1993-97, and 10th in 1998-2002).

4.2. **The countries of the Far East (historic off springs of Chinese civilization**) demonstrated great scientific progress. Japan with its 57% growth was the first among the 7 world leaders. It was followed by 'Asian tigers' - South Korea 455%, Taiwan 422%, Singapore 238%, and Hong Kong 162%, while mainland China (115%) joined in the process by ranking 23rd in 1981-85, 15th in 1989-93 and 1993-97, and 8th in 98-2002.

4.3. Outside these two regions, **Brazil** (with its 80% growth) should be mentioned as well as politically stable **Arabic nations**, such as Egypt, Saudi Arabia, Morocco, Tunis and Jordan (total growth 70%), especially in medicine, engineering, ecology. **South Africa** showed very moderate growth (11%) during last 10 years (1993-2002). **India** with its long standing tradition of European science (it ranked 8th in 1981-85) showed very moderate growth (9%) and was bypassed by Italy. However, it still ranked 3rd in agricultural sciences, and 7th in chemistry and materials science.

4.4. It is well known that some sciences (**physics, astrophysics, chemistry, biology and biochemistry, molecular biology and genetics, neurosciences**) demand huge investments both in equipment and scientific cadres, an aspect that affects **mathematics, too**. It will take decades for the developing countries to build a corresponding infrastructure.

Another circle of sciences consists of applied disciplines (**engineering, agricultural sciences, clinical medicine, computer sciences, material sciences**), where the developing countries have already demonstrated definite progress.

Finally, the third circle of science may be called nature-oriented in its search for experimental material and observation. Here we find **plant and animal sciences, pharmacology, immunology, geosciences**. Much is to be expected from the developing countries in that sphere.

Thanks for your attention and your patience. Ngiyabonga ga-ku-lu!!!