Annals of Library and Information Studies
Vol. 57, June 2010, pp.150-165

Mapping of science and technology output of Brazil during 1997-2007

B.M. Gupta

Emeritus Scientist, National Institute of Science, Technology & Development Studies,
New Delhi- 110012, Email: bmgupta1@gmail.com

Examines Brazil's performance in S&T during 1997-2007 based on several parameters including the country's annual average growth rate, global publication share and rank, strong and weak subject areas (in terms of national priority, international collaborative share and global share), institutional profile of select top institutions, overall international collaboration profile and major collaborative partners, patterns of communication in national and international journals and characteristics of its highly cited papers. The Scopus international multidisciplinary bibliographical database has been used for collecting the publication data of Brazil.

Introduction

At present, CNPq (The National Council for Scientific & Technological Development) dedicated to the promotion of S&T and the development of human resources, CAPES (a division of Ministry of Education that manages masters and doctoral level academic standards and manages international partnership between Brazil and foreign universities) and FINEP (an agency for research and project financing founded in 1967 and also known as Brazil innovation agency) are the three main actors in Brazilian science and innovation. These three agencies work under the auspices of the Ministry of Science and Technology, which coordinates national science and technology policy of Brazil. Several other ministries also coordinate science budgets in their own fields. The states also play a significant role in S&T funding in many places. The 1988 constitution set out a requirement for a science-funding agency in every state, following the path setting example of Sao Paulo in 1962. A National Science and Technology Council was designated to oversee the relationship between the different organizations.

From 2002 to 2007, the world R&D expenditure increased from an estimated $788.5 billion PPP to $1137.9 billion PPP. The Brazilian share in world R&D expenditure increased from 1.5% in 2002 to 1.7% in 2007[1]. The R&D intensity (per cent share of its GDP to R&D) of Brazil increased from 0.94% in 2000 to 1.1% in 2007[2]. In November 1997, the country launched the National Action Plan for S&T 1997-2007, which aims to increase the R&D spending to 1.5 per cent of GDP by 2010. The public sector has historically been the dominant source of funding, although the share of private sector investments has been rising and the balance is now around 50:50 per cent. The number of researchers (measured in full time equivalents-FTE) had increased from an estimated 5.8 million worldwide in 2002 to 7.1 million in 2007. The Brazilian share in total world researchers had increased from 1.2% in 2002 to 1.7% in 2007. There were 1063 researchers per million inhabitants in the world in 2007, compared to just 626 in Brazil[1]. The number of M.Sc students graduating from educational system in Brazil had increased from around 4000 to 32900 and Ph.D students from less than 100 to 9900 from 1987 to 2007[2].

The most recent government Action Plan for S&T highlights the 11 areas of strategic investments such as biotechnology and nanotechnology, ICT, health, biofuels, energy, oil, gas and minerals, agri-science, biodiversity, the Amazon, climate change, space, nuclear science and defence. Since 1999, there has been policy shift from funding purely academic research to public-private collaboration and industrial R&D. The policy had the greatest impact on the Brazilian R&D in the creation of Sectoral Funds. First established in 1998, there are now 16 Sectoral Funds in all major strategic areas of R&D.

Objectives of the study

The main objective of this study is to produce current Brazilian S&T indicators by measuring progress of research in Brazil using publications output data. Such indicators are of special significance to the planners and policy-makers in the country. In this regard the study aims at:

- To analyze Brazil's current publications rate and its global publications share in comparison with select leading countries;
- To compare and understand similarities between Brazil's national research profile and of select leading productive countries;
- To determine most productive and weak subject areas of research in science and technology in Brazil;
- To determine Brazil's share of international collaborative papers in its total output, leading co-author countries collaborating with Brazil as well as its publications share across main subject areas; and
- To understand characteristics of highly productive institutions, scientists and of cited papers.

Methodology

This study uses Scopus database for drawing publications data on Brazil and select countries leading in science and technology. Scopus is an international multidisciplinary database indexing over 15000 international peer reviewed journals in science and technology, besides more than 500 international conference/seminar proceedings. So far Scopus is the single largest international multidisciplinary database in the world. Given its wider coverage of journals and conference/seminar proceedings from developed and developing countries compared to another international multidisciplinary database, the *Web of Science*, the use of Scopus is expected to generate a better picture of Brazilian S&T indicators and hence its selection for this study.

The study uses 11 years publications data from 1997 to 2007 on Brazil and other top 19 productive countries for developing S&T indicators. The study has used a larger data set covering 11 publication years in order to ensure that the study reflects as much accurate and reliable results as possible. In addition, it uses citations data for measuring quality and visibility of Brazil research output. Three years citations window has been used for computing average citations per paper for all S&T papers published by Brazil from 1997 to 2004. But for papers published in 2005 we had to two years citations window and one-year citations window for papers published in 2006. The study has used a number of absolute publications, citation and collaborative measures for developing S&T indicators as needed for depicting Brazil's status in science and technology from 1997 to 2007. A few similar studies have been conducted on Brazil by Glanzel and his co-authors[3,4] and by the present author in collaboration with other colleagues[5].

Analysis

Global share and rank

As reflected in the Scopus database, Brazil published (194 024) research papers during 1997-2007, with an average output of 17,638 papers per year. The cumulative output of Brazil increased from 76 983 papers during 1997-02 to 117 041 papers during 2003-07, showing a growth rate of 52.03 per cent. Brazil achieved an annual average growth rate of 10.97 per cent during 1997-2007. It also improved its annual average growth rate from 9.05 per cent during 1997-02 to 12.90 per cent during 2003-07 (Table 1).

Brazil holds 17th rank among the top 20 most productive countries in science and technology, with its global publications share of 1.27 per cent as computed from cumulative publications data for 1997-2007. Brazil had shown rise in its global publications share, rising from 0.91 per cent to 1.20 per cent and to 1.66 per cent from the year 1997 to the year 2002 and to the year 2007, respectively. Correspondingly Brazil improved its world

Table 1 — Annual publication output and international collaborative papers output of Brazil, 1997-2007

Year	TP	%TICP	Year	TP	TICP
1997	10 289	29.84	2004	20 252	27.6
1998	11 413	29.97	2005	22 499	27.54
1999	12 391	27.85	2006	27 372	25.6
2000	13 388	27.03	2007	28 819	25.63
2001	13 698	22.41	1997-07	194 024	26.69
2002	15 804	22.48	1997-02	76 983	26.60
2003	18 099	27.7	2003-07	117 041	26.82

TP = Total Papers; TICP = Total International Collaborative Papers

Table 2 — Productivity and world publication share and rank of top 20 productive countries in science & technology

Sl. No.	Country	National publication output				Percentage share of national publication output in its total output			
		1997	2002	2007	97-07	1997	2002	2007	97-07
1	USA	314 029	314 530	357 635	3 584 564	27.72	23.79	20.65	23.44
2	UK	124 776	93 234	124 776	1 130 827	11.01	7.05	7.20	7.40
3	Japan	87 750	91 655	98 211	1 057 233	7.74	6.93	5.67	6.91
4	Germany	75 296	80 514	97 200	958 647	6.65	6.09	5.61	6.27
5	China	31 236	62 256	194 241	993 717	2.76	4.71	11.21	6.50
6	France	56 310	57 162	71 984	691 720	4.97	4.32	4.16	4.52
7	Canada	40 236	41 799	62 859	525 931	3.55	3.16	3.63	3.44
8	Italy	38 128	41 875	59 520	510 298	3.37	3.17	3.44	3.34
9	Spain	25 049	30 409	46 808	372 277	2.21	2.30	2.70	2.43
10	Russia	31 040	32 431	30 660	355 564	2.74	2.45	1.77	2.33
11	Australia	23 059	27 410	42 558	337 376	2.04	2.07	2.46	2.21
12	India	21 058	25 990	44 135	322 956	1.86	1.97	2.55	2.11
13	Netherlands	22 094	23 616	33 299	291134	1.95	1.79	1.92	1.90
14	South Korea	11 933	19 651	38 067	257 034	1.05	1.49	2.20	1.68
15	Sweden	17 360	17 173	22 315	212529	1.53	1.30	1.29	1.39
16	Switzerland	15 507	16 034	23 704	207 737	1.37	1.21	1.37	1.36
17	Taiwan	11 575	14 539	27 410	192 106	1.02	1.10	1.58	1.26
18	Brazil	10 289	15 804	28 819	194 024	0.91	1.20	1.66	1.27
19	Poland	11 328	15 037	19 686	177 288	1.00	1.14	1.14	1.16
20	Belgium	11 343	12 659	18 486	157 930	1.00	0.96	1.07	1.03

ranking from 20th position in 1997 to 17th in 2002 and to 15th in 2007 (Table 2).

Strong and weak subject areas

Brazil contributed the highest national publication share (33.80 per cent) in life sciences in its total research output during 1997-2007, followed by 33.06 per cent in physical sciences, 31.71 per cent in heath sciences and 22.48 per cent in engineering sciences during 1997-2007.

As reflected in cumulative Brazilian research output during 1997-07: (i) medicine, agricultural & biological sciences, biochemistry, genetics & molecular biology, physics and engineering are considered as the five high priority areas of Brazil in S&T, each contributing publication share between 10.02 per cent and 27.26 per cent in the cumulative national publication output; (ii) chemical engineering, materials science, immunology & microbiology and mathematics are the four medium productive subjective areas of Brazil research, each contributing between 5.86 per cent to 9.07 per cent share in the cumulative publication output; (iii) pharmacology, toxicology & pharmaceutics, computer science, environmental science, earth & planetary sciences, neurology, chemical engineering, dentistry, veterinary science and energy are the nine low productive subject areas of Brazil, each contributing publications share between 1.39 per cent and 4.50 per cent in cumulative publication output; and (iv) public health and nursing are the two least productive subject areas contributing each less than 1 per cent publication share in cumulative publication output of Brazil during 1997-07 (Table 3).

Table 3 — National publication share and growth of different broad subjects in Brazilian publication output, 1997-07

Most productive subjects	National publication output			National publication output share			Growth per cent 97-99 to 2005-07
	97-99	05-07	97-07	97-99	05-07	97-07	
Medicine	8787	22 750	52 882	25.77	28.91	27.26	12.17
Agriculture & Biological Science	5618	12 224	29 713	16.48	15.53	15.31	-5.73
Biochemistry, Genetics & Molecular Biology	4449	11 012	27 000	13.05	13.99	13.92	7.24
Physics	6244	9764	29 066	18.31	12.41	14.98	-32.25
Engineering	3452	7460	19 440	10.13	9.48	10.02	-6.37
Chemistry	3224	6747	17 592	9.46	8.57	9.07	-9.33
Materials Science	2567	5049	13 942	7.53	6.42	7.19	-14.78
Immunology & Microbiology	2331	4830	12 575	6.84	6.14	6.48	-10.23
Mathematics	2055	4237	11 366	6.03	5.38	5.86	-10.67
Pharmacology, Toxicology & Pharmaceutics	1575	3566	8729	4.62	4.53	4.50	-1.91
Computer Science	1032	3454	7482	3.03	4.39	3.86	45.01
Environmental Science	1340	3437	7860	3.93	4.37	4.05	11.13
Earth & Planetary Science	1668	3007	8094	4.89	3.82	4.17	-21.89
Neurology	1104	2976	7245	3.24	3.78	3.73	16.79
Chemical Engineering	1310	2855	7725	3.84	3.63	3.98	-5.58
Dentistry	294	2406	4333	0.86	3.06	2.23	254.56
Veterinary Science	1058	1823	5057	3.10	2.32	2.61	-25.35
Energy	503	987	2705	1.48	1.25	1.39	-14.99
Nursing	44	654	887	0.13	0.83	0.46	1386.36
Public Health	158	702	1356	0.46	0.89	0.70	344.30

The largest increase of 3.14 per cent (from 25.77 per cent to 28.91 per cent) in national publication share of Brazil from 1997-99 to 2005-07 has been observed in medicine, followed by 2.20 per cent (from 0.86 per cent to 3.06 per cent) in dentistry, 1.36 per cent (from 3.03 per cent to 4.39 per cent) in computer science, 0.94 per cent (from 13.09 per cent to 13.99 per cent) in biochemistry, genetics & molecular biology, 0.70 per cent (from 0.13 per cent to 0.83 per cent) in nursing, 0.54 per cent (from 3.24 per cent to 3.78 per cent) in neurology, 0.44 per cent (from 3.93 per cent to 4.37 per cent) in environmental science and 0.43 per cent (from 0.46 per cent to 0.89 per cent) in public health. In contrast, the largest decrease of 5.91 per cent (from 18.31 per cent to 12.41 per cent) in national publication share of Brazil from 1997-99 to 2005-07 was observed in physics, followed by 1.11 per cent (from 7.53 per cent to 6.42 per cent) in materials science, 1.07 per cent (from 4.89 per cent to 3.82 per cent) in earth & planetary sciences, 0.94 per cent (from 16.48 per cent to 15.53 per cent) in agricultural & biological sciences, 0.88 per cent (from 9.46 per cent to 8.57 per cent) in chemistry, 0.79 per

Table 4 — Global publication share of Brazil in various broad subjects, 1997-07

Subject	World publication output			Brazil publications			World share of Brazil		
	1997	2007	1997-07	1997	2007	1997-07	1997	2007	1997-07
Neurology	36 439	41 330	51 772	314	1088	7245	0.86	2.63	13.99
Dentistry	5997	10 182	83 409	75	928	4333	1.25	9.11	5.19
Veterinary Science.	11 421	18 499	159 541	298	786	5057	2.61	4.25	3.17
Agriculture & Biological Science	85 009	125 374	1 062 887	1658	4711	29 713	1.95	3.76	2.80
Immunology & Microbiology	46 025	59 935	558 409	663	1802	12 575	1.44	3.01	2.25
Mathematics	36 822	91 138	591 725	593	1526	11 366	1.61	1.67	1.92
Physics	121 728	188 804	1 682 738	1876	3382	29 066	1.54	1.79	1.73
Chemistry	87 320	125 302	1 128 376	1013	2405	17 592	1.16	1.92	1.56
Pharmacology, Toxicology & Pharmaceutics	48 726	62 555	594 688	488	1365	8729	1.00	2.18	1.47
Biochemistry, Genetics & Molecular Biology	156 493	232 742	1 958 742	1328	4107	27 000	0.85	1.76	1.38
Environmental Science	50 821	74 440	619 259	440	1287	7860	0.87	1.73	1.27
Medicine	326 811	505 179	4 187 784	2644	8626	52 882	0.81	1.71	1.26
Materials Science	82 436	133 270	1 135 892	704	1689	13 942	0.85	1.27	1.23
Earth & Planetary Science	55 699	74 456	687 735	587	976	8094	1.05	1.31	1.18
Chemical Engineering	37 905	72 243	681 698	388	1062	7725	1.02	1.47	1.13
Computer Science	44 445	123 168	758 454	336	1274	7482	0.76	1.03	0.99
Energy	16 062	37 117	294 373	120	377	2705	0.75	1.02	0.92
Engineering	162 565	281 274	2 500 770	1144	2180	19 440	0.70	0.78	0.78
Public Health	17 832	27 183	240 822	36	315	1356	0.20	1.16	0.56
Nursing	13 035	31 972	200 575	11	350	887	0.08	1.09	0.44

cent (from 3.10 per cent to 2.32 per cent) in veterinary science, 0.70 per cent (from 6.84 per cent to 6.14 per cent) in immunology & microbiology, 0.65 per cent (from 10.13 per cent to 9.48 per cent) in engineering, 0.64 per cent (from 6.03 per cent to 5.38 per cent) in mathematics, 0.22 per cent (from 1.48 per cent to 1.25 per cent) in energy, 0.21 per cent (from 3.84 per cent to 3.63 per cent) in chemical engineering and 0.09 per cent (from 4.62 per cent to 4.53 per cent) in pharmacology, toxicology & pharmaceutics (Table 3).

In terms of global publication share among the 20 broad subject areas during 1997-2007, the largest share (13.99 per cent) of Brazil is accounted by neurology, followed by dentistry (5.19 per cent), veterinary science (3.17 per cent), agricultural & biological sciences (2.80 per cent), immunology & microbiology (2.25 per cent), mathematics (1.92 per cent), physics (1.73 per cent), chemistry (1.56 per cent), pharmacology, toxicology and pharmaceutics (1.47 per cent), biochemistry, genetics & molecular biology (1.38 per cent), environmental science (1.27 per cent), medicine (1.26 per cent), materials science (1.23 per cent), earth & planetary sciences (1.18 per cent), chemical engineering (1.13 per cent), computer science (0.99 per cent), energy (0.92 per cent), engineering (0.78

per cent), public health (0.56 per cent) and nursing (0.44 per cent) (Table 4).

Brazil has improved its global publication share in all the subjects over the years, but the largest increase (7.86 per cent) is achieved by dentistry (from 1.25 per cent to 9.11 per cent) from the year 1997 to the year 2007, followed by 1.81 per cent (from 1.95 per cent to 3.76 per cent) in agricultural & biological sciences, 1.77 per cent (from 0.86 per cent to 2.63 per cent) in neurology, 1.64 per cent (from 2.61 per cent to 4.25 per cent) in veterinary science, 1.57 per cent (from 1.44 per cent to 3.01 per cent) in immunology & microbiology, 1.18 per cent (from 1.0 per cent to 2.18 per cent) in pharmacology, toxicology & pharmaceutics, 1.01 per cent (from 0.08 per cent to 1.09 per cent) in nursing, 0.96 per cent (from 0.20 per cent to 1.16 per cent) in public health, 0.92 per cent (from 0.85 per cent to 1.76 per cent) in biochemistry, genetics & molecular biology, 0.90 per cent (from 0.81 per cent to 1.71 per cent) in medicine, 0.86 per cent (from 0.87 per cent to 1.73 per cent) in environmental science, 0.76 per cent (from 1.16 per cent to 1.92 per cent) in chemistry, 0.45 per cent (from 1.02 per cent to 1.47 per cent) in chemical engineering, 0.41 per cent (from 0.85 per cent to 1.27 per cent) in materials science, 0.28 per cent (from 0.76 per cent to 1.03 per cent) in computer science, 0.27 per cent (from 0.75 per cent to 1.02 per cent) in energy, 0.25 per cent (from 1.54 per cent to 1.74 per cent) in physics, 0.08 per cent (from 0.70 per cent to 0.78 per cent) in engineering and 0.06 per cent (from 1.61 per cent to 1.67 per cent) in mathematics (Table 4).

Institutional profile

Based on publications output data for Brazil in science and technology, a total of 20 institutions were identified as high productive ones publishing more than 2700 papers in the country output during 1997-2007. These top 20 institutions together contributed 123 025 papers (with 63.41 per cent share) in the total cumulative research output by Brazil during 1997-2007.The shares of these top 20 institutions in the total Brazil publication output has increased from 57.72 per cent (44 433 papers) in 1997-02 to 67.15 per cent (78 596 papers) during 2003-07. These institutions individually published between 2760 and 23 401 papers in 11 years (1997-2007), with an average output of 6151 papers per institution. Of these, 6 institutions each contributed publications output above the 20-institutions average (6151 papers per institution) during 1997-2007. These institutions along with their publications output are: Universidade de Sao Paulo with 23 401 papers, followed by Universidade Estadual de Campinas (11 463 papers), Universidade Federal do Rio de Janeiro (9678 papers), Universidade Federal do Rio Grande do Sul (9291 papers), Universidade Federal de Minas Gerais (8023 papers) and Universidade Estadual Paulista Julio de Mesquita Filho (6277 papers) (Table 5).

The average growth rate of the top 20 Brazilian institutions from 1997-02 to 2003-07 was 76.89 per cent. Ten Brazilian institutions achieved higher growth rate than the average growth rate of the top 20 Brazilian institutions from 1997-02 to 2003-07. These are: Universidade Federal de Sao Paulo recorded the highest growth rate of 205.20 per cent, followed by Faculdade de Medicina da Universidade de Sao Paulo (122.00 per cent), Universidade Federal do Parana (96.78 per cent), Universidade Federal do Ceara (96.18 per cent), Universidade Federal do Rio Grande do Sul (95.99 per cent), Universidade de Brasilia (94.56 per cent), Universidade Estadual Paulista Julio De Mesquita Filho (88.73 per cent), Universidade de Sao Paulo (88.53 per cent), Universidade Federal de Pernambuco (81.49 per cent), and Universidade Federal de Santa Catarina (77.65 per cent)(Table 5).

The average share of the international collaborative papers of these 20 Brazilian institutions during 1997-07 was 25.64 per cent. Only 6 out of 20 institutions have shown higher share of international collaboration papers than the average share of 20 institutions. Universidade Federal do Rio de Janeiro recorded the highest share (64.98 per cent) of international collaborative papers, followed by Universidade Federal de Sao Paulo (61.30 per cent share), Faculdade de Medicina da Universidade de Sao Paulo (32.21 per cent share), Universidade Federal Fluminense (30.45 per cent share), Universidade de Brasilia (27.93 per cent share) and Universidade Federal do Parana (27.90 per cent) (Table 6).

The average h-index of the top 20 Brazilian institutions during 1997-07 was 55.20. Of the total institutions, 8 institutions showed h-index higher than the top 20-institutions average. These are: Universidade de Sao Paulo with h-index of 92, followed by Universidade Federal do Rio Grande do Sul (74), Universidade Estadual de Campinas (72), Universidade Federal de Minas Gerais (69), Universidade Federal do Rio de Janeiro (66), Universidade Federal de Sao Paulo (59), Faculdade de Medicina da Universidade de Sao Paulo (57) and

Table 5 — Growth of publications output of top 25 institutions of Brazil, 1997-2007

Sl. No.	Organization / Institute	Total papers			
		1997-07	1997-02	2003-07	Growth 97-02 to 03-07
1	Universidade de Sao Paulo	23 401	8110	15 291	88.55
2	Universidade Estadual de Campinas	11 463	4234	7229	70.74
3	Universidade Federal do Rio de Janeiro	9678	3853	5825	51.18
4	Universidade Federal do Rio Grande do Sul	9291	3139	6152	95.99
5	Universidade Federal de Minas Gerais	8023	2984	5039	68.87
6	Universidade Estadual Paulista Julio De Mesquita Filho	6277	2174	4103	88.73
7	Universidade Federal de Santa Catarina	5081	1830	3251	77.65
8	Universidade Federal de Sao Carlos	5026	2061	2965	43.86
9	Universidade Federal de Sao Paulo	4465	1102	3363	205.20
10	Universidade Federal de Pernambuco	4273	1518	2755	81.49
11	Universidade de Brasilia	4118	1398	2720	94.56
12	Universidade do Estado do Rio de Janeiro	4080	1490	2590	73.83
13	Universidade Federal do Parana	4057	1367	2690	96.78
14	Faculdade de Medicina da Universidade de Sao Paulo	3828	1189	2639	122.00
15	Faculdade de Medicina de Ribeirao Preto da USP	3718	1349	2369	75.61
16	Instituto de Fisica de Universidade de Sao Paulo	3536	1594	1942	21.83
17	Universidade Federal de Sao Paulo Escola Paulista de Medicina	3534	1556	1978	27.12
18	Universidade Federal Fluminense	3241	1316	1925	46.28
19	Universidade Federal do Ceara	3175	1072	2103	96.18
20	Pontificia Universidade Catolica do Rio de Janeiro	2760	1097	1667	51.96
	Total	123 025	44 433	78 596	76.89
	Total Brazil Output	194 024	76 983	117 041	
	Institutional Output in Brazil Output	63.41	57.72	67.15	

Table 6 — Publication output, international collaborative papers and h-index of top 20 institutions from Brazil

Sl. No.	Organization / Institution	TP	TICP 1997-07		h –index
		1997-07	Total	Per cent share	
1	Universidade de Sao Paulo	23 401	2764	11.81	92
2	Universidade Estadual de Campinas	11 463	2439	21.28	72
3	Universidade Federal do Rio de Janeiro	9678	6289	64.98	66
4	Universidade Federal do Rio Grande do Sul	9291	2137	23.00	74
5	Universidade Federal de Minas Gerais	8023	1416	17.65	69
6	Universidade Estadual Paulista Julio de Mesquita Filho	6277	1400	22.30	50
7	Universidade Federal de Santa Catarina	5081	1111	21.87	52
8	Universidade Federal de Sao Carlos	5026	1090	21.69	48
9	Universidade Federal de Sao Paulo	4465	2737	61.30	59
10	Universidade Federal de Pernambuco	4273	856	20.03	42
11	Universidade de Brasilia	4118	1150	27.93	47
12	Universidade do Estado do Rio de Janeiro	4080	1024	25.10	48
13	Universidade Federal do Parana	4057	1132	27.90	46
14	Faculdade de Medicina da Universidade de Sao Paulo	3828	1233	32.21	57
15	Faculdade de Medicina de Ribeirao Preto da USP	3718	926	24.91	56
16	Instituto de Fisica de Universidade de Sao Paulo	3536	899	25.42	54
17	Universidade Federal de Sao Paulo Escola Paulista de Medicina	3534	716	20.26	55
18	Universidade Federal Fluminense	3241	987	30.45	39
19	Universidade Federal do Ceara	3175	597	18.80	42
20	Pontificia Universidade Catolica do Rio de Janeiro	2760	647	23.44	36
		123 025	31 550	25.64	55.2

Faculdade de Medicina de Ribeirao Preto da USP (56) (Table 6).

International collaboration profile

Brazil is having international collaboration with developed and developing countries for research pursuits in science and technology. Based on publications output data for Brazil in science and technology for 1997-2007, it is found that its average annual share of international collaborative papers to its total cumulative publication output was 26.69 per cent. Like most other top countries, Brazil showed increase in its international collaborative papers share

Table 7 — Top 15 most productive countries international collaborative outputs with Brazil, 1997-2007

Country	Collaborative papers			Per cent share of collaborative papers		
	1997-02	2003-07	1997-07	1997-02	2003-07	1997-07
United States	7648	11 728	19 376	37.51	36.95	37.17
France	2752	4228	6980	13.5	13.32	13.39
United Kingdom	2562	4075	6637	12.57	12.84	12.73
Germany	2207	3625	5832	10.82	11.42	11.19
Italy	1341	2196	3537	6.58	6.92	6.79
Canada	1236	2306	3542	6.06	7.27	6.79
Spain	1212	1971	3183	5.94	6.21	6.11
Russia	917	996	1913	4.5	3.14	3.67
Japan	712	1294	2006	3.49	4.08	3.85
Netherlands	558	1129	1687	2.74	3.56	3.24
Switzerland	453	917	1370	2.22	2.89	2.63
Australia	428	1072	1500	2.1	3.38	2.88
India	364	700	1064	1.79	2.21	2.04
China	321	536	857	1.57	1.69	1.64
South Korea	135	362	497	0.66	1.14	0.95
Taiwan	53	162	215	0.26	0.51	0.41
Total	20 388	31 740	52 128			

from 26.60 per cent during 1997-02 to 26.82 per cent during 2003-07 (Table 1).

Among the top countries collaborating with Brazil, the leading ones: United States with 37.17 per cent share in the total international collaborative publications during 1997-07, followed by France (13.39 per cent), UK (12.73 per cent), Germany (11.19 per cent), Italy (6.79 per cent), Canada (6.79 per cent), Spain (6.11 per cent), Russia (3.67 per cent), Japan (3.85 per cent), Netherlands (3.24 per cent), Switzerland (2.63 per cent), Australia (2.88 per cent), India (2.04 per cent), China (1.64 per cent), South Korea (0.93 per cent) and Taiwan (0.41 per cent). With countries like Russia, United States and France, Brazil witnessed decrease in its share of collaborative papers in the total papers from 1997-02 to 2003-07 by 1.36 per cent (from 4.5 per cent to 3.14 per cent), 0.56 per cent (from 37.51 per cent to 36.95 per cent) and 0.18 per cent (from 13.50 per cent to 13.32 per cent). In contrast, Brazil witnessed increase in the international collaborative papers share by 1.28 per cent (from 2.10 per cent to 3.38 per cent) with Australia, 1.21 per cent (from 6.06 per cent to 7.27 per cent) with Canada, 0.82 per cent (from 2.74 per cent to 3.56 per cent) with Netherlands, 0.67 per cent (from 2.22 per cent to 2.89 per cent) with Switzerland, 0.60 per cent (from 2.22 per cent to 2.89 per cent) with Germany, 0.59 per cent (from 3.49 per cent to 4.08 per cent) with Japan, 0.48 per cent (from 0.66 per cent to 1.14 per cent) with South Korea, 0.42 per cent (from 1.79 per cent to 2.21 per cent) with India, 0.34 per cent (from 6.58 per cent to 6.92 per cent) with Italy, 0.27 per cent (from 12.57 per cent to 12.84 per cent) with UK, 0.27 per cent (from 5.94 per cent to 6.21 per cent) with Spain, 0.25 per cent (from 13.50 per cent to 13.32 per cent) with Taiwan and 0.12 per cent (from 1.57 per cent to 1.69 per cent) with China (Table 7).

Among the various subjects, the largest share (65.71 per cent) of international collaborative papers is recorded by Brazil in dentistry during 1997-2007, followed by earth &

Table 8 — Share of international collaborative papers in different broad subjects of Brazil

Broad subjects	International collaborative publication output			International Collaborative publication output share		
	97-99	2005-07	1997-07	97-99	2005-07	1997-07
Medicine	1607	4603	10 031	18.29	20.23	18.97
Chemistry	940	1513	4206	29.16	22.42	23.91
Physics	2591	3791	11 133	41.50	38.83	38.30
Agriculture & Biological Sciences	1739	3024	7651	30.95	24.74	25.75
Engineering	664	1976	4467	19.24	26.49	22.98
Biochemistry, Genetics & Molecular Biology	1569	3150	7967	35.27	28.61	29.51
Material Science	779	1417	3990	30.35	28.06	28.62
Earth & Planet Science	826	1423	3962	49.52	47.32	48.95
Environmental Science	512	1217	2853	38.21	35.41	36.30
Pharmacy, Toxicology & Pharmaceutics	394	675	1758	25.02	18.93	20.14
Chemical Engineering	296	634	1659	22.60	22.21	21.48
Mathematics	791	1581	4250	38.49	37.31	37.39
Immunology & Microbiology	827	1509	3899	35.48	31.24	31.01
Computer Science	266	1061	2116	25.78	30.72	28.28
Neurology	276	765	1739	25.00	25.71	24.00
Veterinary Science	172	331	844	16.26	18.16	16.69
Energy	123	230	607	24.45	23.30	22.44
Nursing	19	124	196	43.18	18.96	22.10
Public Health	71	211	442	32.60	44.94	30.06
Dentistry	791	1581	4250	98.08	269.05	65.71

planetary sciences (48.95 per cent), physics (38.30 per cent), mathematics (37.39 per cent), environmental science (36.30 per cent), immunology & microbiology (31.01 per cent), public health (30.06 per cent), biochemistry, genetics & molecular biology (29.51 per cent), materials science (28.62 per cent), computer science (28.28 per cent), agricultural & biological sciences (25.75 per cent), neurology (24.80 per cent), chemistry (23.91 per cent), engineering (22.98 per cent), energy (22.44 per cent), nursing (22.10 per cent), chemical engineering (121.48 per cent), pharmacology, toxicology & pharmaceutics (20.14 per cent), medicine (18.97 per cent) and veterinary science (16.69 per cent). Brazil's share of international collaborative papers had decreased in 14 subjects from 1997-99 to 2005-07. The largest decrease (29.03 per cent) in international collaborative papers share was recorded from 1997-99 to 2005-07 in dentistry, followed by nursing (24.22 per cent), chemistry (6.74 per cent), biochemistry, genetics & molecular biology (6.66 per cent), agricultural & biological sciences (6.21 per cent), pharmacology, toxicology & pharmaceutics (6.09 per cent), immunology & microbiology (4.24 per cent), environmental science (2.80 per cent), physics (2.67 per cent), materials science (2.29 per cent), earth & planetary sciences (2.20 per cent), mathematics (1.18 per cent), energy (1.15 per cent) and chemical engineering (0.39 per cent). Brazil's share of international collaborative papers had increased

Table 9 — List of most productive journals publishing Brazilian research output

Sl. No.	Journals	Number of papers		
		1997-02	2003-07	1997-07
1	*Arquivos De Neuro Psiquiatria*	917	1079	1996
2	*Pesquisa Agropecuaria Brasileira*	1371	592	1963
3	*Brazilian Journal of Medical & Biological Research*	987	932	1919
4	*Arquivos Brasileiros De Cardiologia*	774	1069	1843
5	*Quimica Nova*	647	963	1610
6	*Physical Review B.Condensed Matter & Materials Physics*	741	789	1530
7	*Memorias do Instituto Oswald Cruz*	776	690	1466
8	*Brazilian Journal of Physics*	475	804	1279
9	*Lecture Notes in Computer Science Including Sub series Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics*	…	1270	1270
10	*Journal of the Brazilian Chemical Society*	499	726	1225
11	*Revista De Saude Publica*	469	673	1142
12	*Revista Brasileira De Zootecnia*	824	233	1057
13	*Genetics and Molecular Biology*	394	491	885
14	*Physica A. Statistical Mechanics & Its Applications*	414	468	882
15	*Revista Brasileira De Otorrinolaringologia*	408	431	839
16	*Arquivo Brasileiro De Medicina Veterinaria E Zootecnia*	390	402	792
17	*Proceedings of SPIE the International Society for Optical Engineering*	414	374	788
18	*Anais Brasileiros De Dermatologia*	420	355	775
19	*Brazilian Archives of Biology 7Technology*	174	559	733
20	*Journal of Applied Physics*	346	355	701
21	*Revista Brasileira De Medicina*	401	289	690
22	*Physical Review D. Particles Fields Gravitation and Cosmology*	350	333	683
23	*Brazilian Journal of Microbiology*	204	458	662
24	*Jornal De Pediatria*	158	495	653
25	*Physical Review Letters*	280	366	646
26	*Physical Review E. Statistical Nonlinear and Soft Matter Physics*	194	446	640
27	*Revista Da Sociedade Brasileira De Medicina Tropical*	179	455	634
28	*Materials Science Forum*	216	418	634
29	*Revista do Instituto De Medicina Tropical De Sao Paulo*	340	292	632
30	*Ciencia Rural*	0	631	631
31	*Cadernos De Saude Publica*	9	611	620
32	*Physical Review A. Atomic Molecular and Optical Physics*	303	317	620
33	*Physics Letters Section B Nuclear Elementary Particle and High Energy Physics*	365	254	619
34	*SBMO IEEE MTT S International Microwave and Opt electronics Conference Proceedings*	227	354	581
35	*Arquivos Brasileiros De Oftalmologia*	58	505	563
36	*Journal of Magnetism & Magnetic Materials*	249	313	562
37	*Astronomy & Astrophysics*	215	334	549
38	*Brazilian Journal of Chemical Engineering*	304	245	549
39	*Revista Brasileira De Anestesiologia*	278	270	548
40	*Anais Da Academia Brasileira De Ciencias*	286	249	535
	Total	16056	20890	36946
	Country Output	76983	117041	194024

Table 10 — List of Top 20 Most High Cited Papers of Brazil, 1998-2007

Authors	Affiliations	Title	Source title	No. of Citations
Fried M.W., Shiffman M.L., Rajender Reddy K.,et al.	University of North Carolina, Chapel Hill, United States; Cidade UniversitÃ¡ria Zeferino Vaz, Campinas, Brazil	Peginterferon alfa-2a plus ribavirin for chronic hepatitis C virus infection (Article)	New England Journal of Medicine 2002, 347(13), 975-982	2288
Bombardier C., Laine L., Reicin A.,et al.	University Health Network, Toronto, Ont., Canada; Universidade Federal de SÌƒo Paulo, Department of Medicine, SÌƒo Paulo, Brazil	Comparison of upper gastrointestinal toxicity of rofecoxib and naproxen in patients with rheumatoid arthritis (Article)	New England Journal of Medicine 2000, 343(21), 1520-1528	2267
Morice M.-C., Serruys P.W., Eduardo Sousa J.,et al.	Institut Cardiovasculaire Paris Sud, Massy, France; Institute Dante Pazzanese de Cardiologia, SÃ£o Paulo, Brazil	A randomized comparison of a sirolimus-eluting stent with a standard stent for coronary revascularization (Article)	New England Journal of Medicine 2002, 346(23), 1773-1780	1951
Dupont J., De Souza R.F., Suarez P.A.Z. ,et al.	UFRGS, Institute of Chemistry, Porto Alegre , Brazil; University of SÃ£o Paulo,Heart Institute, SÃ£o Paulo, Brazil	Ionic liquid (molten salt) phase organometallic catalysis (Article)	Chemical Reviews 2002, 102(10), 3667-3692	1429
Racusen L.C., Solez K., Colvin R.B.,et al.	Johns Hopkins Univ. Sch. of Medicine, Baltimore, MD, United States; SÃ£o Paulo University, SÃ£o Paulo, Brazil	The Banff 97 working classification of renal allograft pathology (Article)	Kidney International 1999, 55(2), 713-723	1311
Amato M.B.P., Barbas C.S.V., Medeiros D.M.,et al.	SÃ£o Paulo University, Brazil; University of SÃ£o Paulo,Respiratory Intensive Care	Effect of a protective-ventilation strategy on	New England Journal of Medicine	1297

	Unit, Hospital das ClÃ-nicas, Brazil	mortality in the acute respiratory distress syndrome (Article)	1998, 338(6), 347-354	
Holben B.N., Eck T.F., Slutsker I.,et al.	University of SÃ£o Paulo, Hospital das ClÃ-nicas, Brazil; Instituto de Pesquisas Espaciais, Sao JosÃ© dos Campos, Brazil	AERONET - A federated instrument network and data archive for aerosol characterization (Article)	Remote Sensing of Environment 1998, 66(1), 1-16	1125
Shepherd F.A., Pereira J.R., Ciuleanu T.,et al.	NASA/Goddard Space Flight Center, Greenbelt, MD, United States; Instituto de Cancer Arnaldo Vieira de Carvalho, SÃ£o Paulo, Brazil	Erlotinib in previously treated non-small-cell lung cancer (Article)	New England Journal of Medicine 2005, 353(2), 123-132	1023
Carpenter C.C.J., Cooper D.A., Fischl M.A.,et al.	University Health Network, Department of Medical Oncology and Hematology,Toronto; Univ. Federal Do Rio de Janeiro, Rio de Janeiro, Brazil	Antiretroviral therapy in adults: Updated recommendations of the International AIDS Society-USA panel (Review)	New England Journal of Medicine 2005, 283(3), 381-390	873
Piccart-Gebhart M.J., Procter M., Leyland-Jones B.,et al.	Brown University School of Medicine, Miriam Hospital, United States; PontifÃ¬cia Universidad CatÃ²lica do Rio Grande, Sul School of Medicine, Porto Alegre, Brazil	Trastuzumab after adjuvant chemotherapy in HER2-positive breast cancer (Article)	New England Journal of Medicine 2005, 353(16), 1659-1672	826
Poncharal P., Wang Z.L., Ugarte D.,et al.	Jules Bordet Institute, Medicine Department, Brussels, Belgium; Lab. National de Luz Sincrotron, Campinas SP, Brazil	Electrostatic deflections and	Science 1999,	762

		electromechanical resonances of carbon nanotubes (Article)	283(5407),1513-1516	
Girardi L., Bressan A., Bertelli G.,et al.	Georgia Institute of Technology, School of Physics, Atlanta; Universidade Federal do Rio Grande do Sul, Instituto de FÃ-sica, Porto Alegre RS, Brazil	Evolutionary tracks and isochrones for low- and intermediate-mass stars: From 0.15 to 7 MâŠ™, and from Z = 0.0004 to 0.03 (Article)	Astronomy and Astrophysics Supplement Series 2000, 141(3), 371-383	750
Gluckman E., Rocha V., Boyer-Chammard A.,et al.	UniversitÃ di Padova, Dipartimento di Astronomia, Padova, Italy; Hospital de Clinicas, Curitiba, Brazil	Outcome of cord-blood transplantation from related and unrelated donors (Article)	New England Journal of Medicine 1997, 337(6), 373-381	714
Weaver W.D., Simes R.J., Betriu A.,et al.	HÃ´pital Saint-Louis, Paris, France; University of Pavia, Pavia, Italy; Unicor Hospital, Sao Paulo, Brazil	Comparison of primary coronary angioplasty and intravenous thrombolytic therapy for acute myocardial infarction: A quantitative review (Review)	Journal of the American Medical Association 1997, 278(23), 2093-2093-2098	703
Thomas C.D., Cameron A., Green R.E.,et al.	Heart and Vascular Institute, Henry Ford Health System, Detroit, MI, United States; Ctro. de Ref. Informacao Ambiental, Av. Romeu TÃ³rtima 228,Campinas, SP, Brazil	Extinction risk from climate change (Article)	Nature 2004, 427(6970), 145-148	690
Coutinho M., Gerstein H.C., Wang Y.,et al.	University of Leeds, School of Biology, Leeds, United Kingdom; Federal University of Santa Catarina, Department of Clinical Medicine, Florianopolis, Brazil	The relationship between glucose and incident cardiovascular events: A metaregression analysis of published data from 20 studies of 95,783 individuals followed for 12.4 years (Article)	Diabetes Care 1999, 22(2), 233-240	645
Harper D.M., Franco E.L., Wheeler C.,et al.	Hamilton Civic Hospitals Res. Center, Prev. Cardiol.	Efficacy of a bivalent L1 virus-like particle vaccine in prevention of infection with human papillomavirus types	Lancet Oncology 2004, 364(9447), 1757-1765	642

	Therapeut. Res. Prog., Hamilton, Ont., Canada; Univ. Federal Do Rio Grande Do Sul, Porto Alegre, Brazil	16 and 18 in young women: A randomised controlled trial (Article)		
Grines C.L., Cox D.A., Stone G.W.,et al.	Dartmouth Medical School, Depts. Obstet. Gynecol. Comm. F., Hanover, NH, United States; Inst. Dante Pazzanese de Cardiologia, SÃ£o Paulo, Brazil	Coronary angioplasty with or without stent implantation for acute myocardial infarction (Article)	New England Journal of Medicine 1999, 341(26), 1949-1956	597
Stein R.T., Sherrill D., Morgan W.J.,et al.	William Beaumont Hospital, Division of Cardiology, Royal Oak, MI, United States; Pont. Univ. C., Depto. Pediat., Porto Alegre, Brazil	Respiratory syncytial virus in early life and risk of wheeze and allergy by age 13 years (Article)	Lancet 1999, 354 (9178), 541-545	596
Mora-Duarte J., Betts R., Rotstein C.,et al.	The University of Arizona, Tucson, AZ, United States; UNIFESP, SÃ£o Paulo, Brazil	Comparison of caspofungin and amphotericin B for invasive candidiasis (Article)	New England Journal of Medicine 2002, 347(25), 2020-2029	585

in 6 subjects from 1997-99 to 2005-07. The largest increase (12.34 per cent) in international collaborative papers share was recorded from 1997-99 to 2005-07 in public health, followed by engineering (7.25 per cent), computer science (4.94 per cent), medicine (1.94 per cent), veterinary science (1.90 per cent), and neurology (0.71 per cent)(Table 8).

Research communication in local & foreign journals

The top 40 productive journals together contributed 19.04 per cent share to the total cumulative publications output by Brazil for 1997-2007. Their cumulative publications share also showed decrease from 20.86 per cent to 17.85 per cent from 1997-02 to 2003-2007. Brazil's output in high impact journals (with IF range from 10 to 47.4 citations per journal) was also analyzed on its total publications output data for 1997-07. Brazil published less than one percent (0.50 per cent) of its publications output in high impact journals (Table 9).

Highly cited papers

The top 100 most cited papers from Brazil published during 1997 to 2007 received from 263 to 2288 citations per paper since their publication till the end of 2008. Of these 100 papers, 77 were articles, 19 review papers, 3 short surveys and 1 conference paper. All these 100 high-cited papers were collaborative in nature.

Among the Brazilian institutions, the largest participation is from University of Sao Paulo, Sao Paulo in 14 papers, followed by Institute Dante Pazzanese de Cardiologia, Sao Paulo, Brazil (6 papers), Univ. Federal Do Rio de Janeiro, Rio de Janeiro, Brazil (5 papers), Instituto de QuÃ-mica, Araraguara, SP, Brazil (3 papers), Ctro. Bras.

de Pesq. Fascias, Rio de Janeiro, Brazil (2 papers), Dante Pazzanese Cardiology Institute, Sao Paulo (2 papers), Fed. University of Rio Grande do Sul, Porto Alegre (2 papers), Inst. Dante Pazzanese de Cardiologia, Sao Paulo (2 papers), Inst. de Infectologia Emilio Ribas, Sao Paulo (2 papers), Instituto de Fisica, Porto Alegre (2 papers), Instituto de Pesquisas , Sao Paulo (2 papers), Lab. Nacional de Luz Sincrotron, Campinas SP (2 papers), Pont. Univ. C., Depto. Pediat., Porto Alegre (2 papers), State University of Campinas, Campinas, SP (2 papers), UNIFESP, Sao Paulo (2 papers), Univ. do Estado do Rio de Janeiro, Rio de Janeiro (2 papers), Univ. E., Depto. de Patologia Cia-nica, SP (2 papers) and 1 each from 52 other organizations.

Of these 100 high-cited papers, 89 papers involve international collaboration (21 bilateral collaboration and 68 multilateral collaboration) and 11 involve national collaboration Of the 100 high-cited papers, 69 papers have received the citations from 263 to 492, 23 papers citations from 509 to 873, 5 papers citations from 1023 to 1429, 1 paper 1951 citation and 2 papers citations from 2267 to 2288. These 100 higher cited papers were published in 47 journals including 14 papers each in *Lancet* and *New England Journal of Medicine*, 6 papers each in *Circulation, Journal of American Medical Association and Science*, and 2 papers each in *Chemical Reviews, Diabetes Care, Remote sensing of Environment, Astronomy & Astrophysics Supplement, Lancet Oncology, Nuclear Physics A, Physics Report*, and one each in 34 other journals. Table 10 provides the list of top 20 highly cited papers of Brazil.

Conclusion

The findings and the analysis show that Brazil has made considetable progress in R & D works in the field of S & T during 1997-2007, the period of study for this paper. During this period, Brazil has increased its share of global publication and thereby improved its world ranking from 20th position in 1997 to 15th position in 2007 amongst the top 20 most productive countries in the field of S & T. There has been a significant increase in the annual average growth rate of publication. At the national level, the high priority areas include medicine, agricultural & biological sciences, biochemistry, genetics and molecular biology, physics and engineering. However, public health and nursing are the two least productive subject areas. It is necessary to look into the factors that are responsible for such low productivity in these subject areas. In terms of global publications share among 20 broad subject areas public health and nursing have made the least impact whereas largest share is accounted by neurology followed by dentistry, veterinary science, agriculture & biological sciences, immunology & microbiology, mathematics, physics, chemistry, toxicology and pharmaceutics, biochemistry, genetics and molecular biology, environmental science, medicine.

Based on publications output data in S & T, a total of 20 institutions are identified as high productive ones in Brazil. Only 6 of these 20 institutions have shown higher share of the international collaboration papers than the average share of 20 institutions. Universidade Federal de Rio de Janeiro has recorded the highest share. Like most other top countries, Brazil also showed increase in their international collaborative paper share. However the analysis performed in this paper shows that the output of Brazil in high impact journals is less than 1%. This is again an issue which needs to be looked into by the policy makers of Brazil so as to improve its position in the world in the field of S & T.

All the achievements of Brazil in S & T within the short span of 11 years (1997-2007) can be attributed directly to the Government policy of launching the National Action Plan for S & T 1997-2007. As a result of this, R & D intensity of Brazil has increased from 0.94% in 2000 to 1.1% in 2007. The National Action Plan aims to increase R & D spending to 1.5% of GDP by 2010 with thrust areas such as biotechnology & nanotechnology, ICT, health, biofuels, energy and others. The entrepreneurship from the Government as well as from the private sector in R & D works particularly in the field of S & T is expected to raise the quality as well quantity of the S & T output of Brazil in the coming years.

References

1. A global perspective on research & development. Available at; *http://www.unesco.org/science/psd/wsd07/Fact_Sheet_2009.pdf* (Accessed on 15 March 2010)
2. Innovation Policy Knowledge Base in Brazil. Available at *http://www.visioneranet.org/files/462/Arbix_Innovation_Policy_Knowledge_Base_in_Brazil.pdf* (Accessed on 15 March 2010)
3. Glanzel W, Lete J and Thijs B. Science in Brazil. Part 1: A macro level comparative analysis, *Scientometrics,* 67 (1) (2006) 67-86.
4. Leta J., Glanzel, W Thijs, B. Science in Brazil. Part 2: Sectoral and institutional research profiles, *Scientometrics*, 67 (1) (2006) 87-105
5. Gupta B M, Status of India in science and technology as reflected in its publication output in Scopus international database, 1996-06, New Delhi; NISTADS. 1997