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Mapping of Indian Science and Technology Output in a National and Global Context, 1997-2007

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Introduction

Science and technology pursuit has been a major planning objective of the country, identified on purpose to initiate, advance and accelerate national development in all sectors of economy. Consequent upon this policy initiative, India has been able to usher significant growth in its capacity and capability in basic, applied, and developmental research in science and technology. The investments in S&T have also grown many-fold, from Rs.760.5 crore in 1980 to about Rs.16,361 crore in 2005-06. The total annual expenditure on science and technology is now close to 0.8% of the Gross National Product (GNP). If the government's vision at present is to be believed, the size of the education sector will grow almost 10-fold during the current XI Five-Year Plan. Given these projections in the higher education sector in the country, S&T infrastructure in India is certain to witness significant expansion too in the near future.

Several bibliometric studies have so far attempted to look at indicators as required for understanding the status of science and technology in India¹⁻⁷. They had focused on developing indicators on institutional productivity, national productivity, scattering of research across Indian & foreign journals, quality of research, and nature of collaboration, etc. Another important study⁸ by the authors to this paper, conducted recently under the sponsorship of the Office of the Principle Scientific Advisor (PSA) to the Government of India, had reported several important indicators to understand the progress in Indian science and technology, covering the period 1985-1986, 1995-2006 and 2001-2002. The present study in particular analyses the role and contribution of Indian science in global context. It also compares the similarity of Indian research profile with other top productive countries and particularly with China, South Korea and Brazil.

Objectives

The main objective of this study is to produce current Indian S&T indicators by measuring progress of research in India using publications output data. In this

regard the study aims at: (i) analyzing India's current publications rate and its global publications share in comparison with select leading countries, (ii) comparing and understanding similarities between India's national research profile and of select leading productive countries; (iii) determining most productive and weak subject areas of research in Indian science and technology; (iv) the share of Indian science in global output in overall as well as across various subjects; and (v) comparing Indian science with China, South Korea and Brazil S&T.

Methodology and Data Source

This study uses Scopus database for drawing publications data on India and select countries leading in science and technology. Scopus is an international multidisciplinary database indexing over 15,000 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 (including from India and China) compared to another international multidisciplinary database such as *Web of Science* database, the use of Scopus is expected to generate a better picture of Indian S&T indicators and hence its selection for this study.

The study uses 11 years publications data from 1997 to 2007 on India and other top 19 productive countries for developing S&T indicators. The study has purposely used larger data set covering 11 publication years in order to ensure that the study reflects a more accurate and reliable results as possible. In addition, it used citations data for measuring quality and visibility of Indian research output. Three years citations window has been used for computing average citations per paper for all S&T papers published by India 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 India's status in science and technology from 1997 to 2007.

Analysis

India's Publication Share and Rank in World

India ranks 12th among the top 20 productive countries in science and technology, with its global publications share of 2.11% as computed from cumulative world publications data for 1997-2007 (Table 1). The other countries in the top 20 list that contributed world share similar to that of India are Russia, Spain, and Australia (in the range 2.0% to 2.50%). In overall, the global publication shares of the top 20 productive countries in S&T from 1997-2007 ranged from 1.03% to 23.44%. The United States tops the list with its global publication share of 23.44%, and followed far behind are United Kingdom, Japan, China, Germany, and France (their global publication share ranging 4.5% to 7.4%). The countries that rank between 13th and 20th positions are Netherlands, South Korea, Sweden, Switzerland, Taiwan, Brazil, Poland and Belgium with their global publication share ranging 1% to 1.9% (Table 1).

Declining Global Publication Share of Developed Countries: The publications activity of most developed countries is gradually declining over time in global context. This is evident from declining trend in their global publications share figures for 1997, 2002 and 2007. In particular, the developed countries that have shown decline in their global publication share are many, including United States, United Kingdom, Japan, Germany, France, Russia, Netherlands and Sweden. The countries from the developed world that have however, shown rise in their global publication share over time are relatively few, including Italy, Australia, Spain,

19	Poland	11,328	15,037	19,686	177,288	1.00	1.14	1.14	1.16	19	18	19	19
20	Belgium	11,343	12,659	18,486	157,930	1.00	0.96	1.07	1.03	18	20	20	20

Rising Global Publication Share of Developing Countries: All developing countries in top 20 productive countries list have shown rising trend in their global publications share over time. China, in particular, has shown strikingly significant rise in its publications share, rising from 2.76% to 4.71%, and to 11.21% in the years 1997, 2002, and 2007 respectively. Correspondingly China improved its world ranking from 8th position in 1997 to 5th in 2002 and to 2nd in 2007. South Korea has also improved its world share (from 1.05% to 1.49% and to 2.20%), Taiwan (from 1.02% to 1.10% and to 1.58%), and Brazil (from 0.91% to 1.20% and to 1.66%) during corresponding years. The world ranking of these three developing countries also improved - South Korea (from 16th to 14th and to 12th), Taiwan (from 17th to 19th and to 16th), and Brazil (from 20th to 17th and to 15th) during corresponding years.

India also witnessed rise in its world publications share. The shift in its global share was from 1.86% to 1.97% and to 2.55% in 1997, 2002, and 2007, respectively. Correspondingly, it improved its world ranking from 13th position in 1997 to 12th in 2002 and to 10th in 2007 (Table 1).

India's Publication Growth Rate in World Context

The developed and developing countries differ significantly in their annual average publication growth rate as seen from their annual publications output data for 1997 to 2007 in S&T. It was 2.23% to 6.54% for developed countries and 7.76% to 20.96% for developing world countries. Whereas the developed countries maintained slow pace of growth in their publications output, the developing countries on the other hand have shown significantly faster growth rate (Table 2-3).

India achieved annual average growth rate in publications output at 7.76% as seen from its publications output data for 1997-2007. China showed growth rate of 20.96% per annum, the highest amongst top 20 countries, followed by South Korea (12.49%), Brazil (10.97%), Taiwan (9.21%), and India (7.76%). Indian ranks last among the developing countries in terms of pace of growth in its publications output (Table 3).

All countries from the developing world (among top 20 productive countries) have shown growth rate of their annual publications output higher than the world average (4.41%). The countries from the developed world (among top 20 productive countries) that have shown growth rate higher than the world average (4.41%) during 1997-2007 include Spain (6.54%), Australia (6.39%), Poland (5.93%), Belgium (5.15%), Canada (4.73%), Italy (4.64%) and Switzerland (4.56%) (Table 3).

Growth rate of publications output by developing world countries has also changed over time. Based on publications output data for 1997-2002 and 2003-2007, it was found that China improved its growth rate from 15.37% to 26.54%, India from 4.31% to 11.21%, Taiwan from 4.70% to 13.71%, South Korea from 10.56% to 14.42% and Brazil from 9.05% to 12.90%. The productive developed world countries have also shown similar trend (Table 3).

Table 2: Annual Publications Output in Science and Technology of Select Countries

	Annual Publications Output, 1997-2007						

Publication Year	World	USA	UK	Japan	Germany	China	France
1997	1133009	314029	88926	87750	75296	31236	56310
1998	1137270	312392	90710	88498	77970	36463	57326
1999	1138939	309609	90751	91229	79112	37632	58497
2000	1205466	313243	95364	92608	80655	45852	58526
2001	1299195	309114	90499	90080	80412	60936	56881
2002	1322231	314530	93234	91655	80514	62256	57162
2003	1376155	334863	103655	98597	90631	74896	63654
2004	1524777	318306	110274	102534	94479	111274	67060
2005	1685487	343011	118390	108768	101171	157893	71800
2006	1734750	357832	124248	107303	101207	181038	72520
2007	1732168	357635	124776	98211	97200	194241	71984

Publication Year	Annual Publications Output, 1997-2007					
	Canada	Italy	Russia	Spain	Australia	Netherlands
1997	40236	38128	31040	25049	23059	22094
1998	39321	37525	32275	25769	23915	22506
1999	38978	38540	30983	27257	24317	22086
2000	39910	39721	31796	27540	25344	22859
2001	39072	40629	32565	28253	26425	22436
2002	41799	41875	32431	30409	27410	23616
2003	48641	48304	32987	35055	30999	27035
2004	53427	51927	34090	37944	34631	29244
2005	59653	55407	35486	42206	37689	32398
2006	62035	58722	31261	45987	41129	33561

2007	62859	59520	30660	46808	42558	33299
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Publication Year	Annual Publications Output, 1997-2007						
	South Korea	Sweden	Taiwan	Brazil	Poland	Belgium	India
1997	11933	17360	11575	10289	11328	11343	21058
1998	12647	17818	11907	11413	11588	12141	21698
1999	14665	17725	12216	12391	12324	12161	22845
2000	16532	17643	12781	13388	13062	12104	23284
2001	18557	17439	14103	13698	13784	12094	24280
2002	19651	17173	14539	15804	15037	12659	25990
2003	24777	19747	16720	18099	17746	15022	29972
2004	29126	20829	20855	20252	19416	16027	32311
2005	33767	22141	23902	22499	21059	17726	36403
2006	37312	22339	26098	27372	22258	18167	40980
2007	38067	22315	27410	28819	19686	18486	44135

Table 3: Annual Average Publications Growth Rate of Select Developed and Developing Countries

Country	Average Annual Publication Growth Rate			Country	Average Publication Growth Rate		
	97-07	97-2002	2003-07		97-07	97-02	2003-07
World	4.41	3.18	5.64	Sweden	2.65	-0.21	5.51
United States	1.37	0.04	2.71	China	20.96	15.37	26.54
UK	3.54	1.01	6.06	India	7.76	4.31	11.21
Japan	1.23	0.89	1.57	South Korea	12.49	10.56	14.42
Germany	2.68	1.36	3.99	Belgium	5.15	2.26	8.04

France	2.56	0.32	4.81	Brazil	10.97	9.05	12.9
Italy	4.64	1.91	7.38	Taiwan	9.21	4.70	13.71
Netherlands	4.32	1.38	7.25	Russia	-0.01	0.92	-0.94
Spain	6.54	3.98	9.10	Poland	5.93	5.85	6.01
Switzerland	4.56	0.37	4.2	Canada	4.73	0.82	8.64
Australia	6.39	3.52	9.25				

Subject Priorities of Top 20 Productive Countries as reflected in their Cumulative Publication Output during 1997-2007

Subject priorities of top 20 productive countries in research have been determined by computing their national publications share in broad disciplines including physical, engineering, life, and health sciences as defined by Scopus based on their publications output for 1997-2007. The strength of national publication share of a country in a discipline reflects its research priority in the subject comparison to other disciplines. The higher the productivity the higher priority of the country in the discipline (Table 4-5).

For example, India's national publications share has been the highest (41.07%) in physical sciences, followed by life sciences (29.68%), engineering sciences (29.59%), and health sciences (22.06%). Given this data, one can conclude India's order of priority in research by discipline. Its priority is the highest to physical sciences, followed by life sciences, engineering sciences, and health sciences. In the world context, India's national publications share in physical sciences, life sciences, and engineering sciences each has been above the global average in each discipline. But in health sciences its share has been below the global average (Table 4-5).

For clarification it may be stated that according to Scopus classification physical sciences discipline includes subjects such as physics, chemistry, mathematics, earth & planetary sciences and environmental sciences. Similarly, life sciences include subjects such as agricultural & biological sciences, biochemistry, genetics & molecular biology, pharmacology, toxicology & pharmaceuticals, immunology & microbiology and neurology. Engineering sciences includes subjects such as engineering, materials science, computer science, chemical engineering and energy. Health sciences include subjects such as medicine, public health, nursing, dentistry and veterinary science.

Table 4: Subject Priorities of Top 20 Productive Countries as reflected in their Cumulative Publications Output during 1997-2007

Country	Total Papers	Percentage Share of Papers under the following Broad Fields			
		Physical Sciences	Engineering Sciences	Life Sciences	Health Sciences
World	15289447	27.90	29.10	23.87	29.58

USA	3584564	26.42	20.87	31.09	33.94
UK	1130827	26.12	19.34	31.94	36.67
Japan	1057233	33.72	31.94	28.37	26.77
Germany	958647	37.48	23.84	26.80	30.15
China	993717	38.97	51.60	15.12	11.25
France	691,720	37.56	24.47	28.21	29.28
Canada	525,931	29.02	23.97	29.86	29.69
Italy	510,298	34.37	21.91	28.74	34.70
Russia	355,564	63.57	35.11	17.30	3.65
Spain	372,277	36.21	21.36	31.14	32.10
Australia	337,376	27.97	18.90	31.67	34.17
India	322,947	41.07	29.59	29.68	22.06
Netherlands	291,134	28.06	19.78	30.85	37.62
South Korea	257,034	38.75	50.18	23.33	14.81
Sweden	212,529	29.50	21.48	33.12	34.57
Switzerland	207,737	35.10	19.92	29.41	32.75
Taiwan	192,106	33.52	46.99	18.29	22.47
Brazil	194,024	33.06	22.48	33.80	31.71
Poland	177,288	47.75	27.55	25.86	23.34
Belgium	157,930	31.38	22.09	30.57	35.17

Table 5: Broad Discipline wise Output of Top 20 Productive Countries as reflected in their Cumulative Publications Output during 1997-2007

Country	Total Papers	Count of Papers under the following Broad Fields			
		Physical Sciences	Engineering Sciences	Life Sciences	Health Sciences

World	15289447	4265794	4449992	3650321	4523136
USA	3584564	947174	748162	1114412	1216646
UK	1130827	295387	218693	361165	414707
Japan	1057233	356479	337640	299930	282999
Germany	958647	359270	228576	256896	289079
China	993717	387281	512773	150276	111822
France	691,720	259797	169293	195147	202527
Canada	525,931	152647	126049	157029	156137
Italy	510,298	175383	111813	146644	177075
Russia	355,564	226022	124855	61517	12992
Spain	372,277	134814	79518	115910	119485
Australia	337,376	94369	63767	106854	115274
India	322,947	132623	95555	95846	71254
Netherlands	291,134	81681	57578	89803	109515
South Korea	257,034	99594	128990	59970	38057
Sweden	212,529	62704	45654	70380	73474
Switzerland	207,737	72918	41386	61104	68029
Taiwan	192,106	64397	90280	35145	43172
Brazil	194,024	64153	43612	65572	61523
Poland	177,288	84649	48847	45853	41387
Belgium	157,930	49566	34893	48279	55548

Similarities in the research profile of India with other 19 productive countries were determined based on similarities in their global publication share by subject. In this regard, based on strength of their national publications share in the subject as compared to the world average, 20 countries were first categorized into four major groups. The following criteria were used to categorize them as strong, moderately strong, moderately weak and weak countries in different broad disciplines.

(i) Strong – Countries having national publication share in the broad subject above

the world average by 5% or more;

(ii) Moderately Strong – Countries having national publication share in the broad subject above the world average by 0.1% to 4.99%;

(iii) Moderately Weak – Countries having national publication share in the broad subject below the world average by 0.1% to 4.99%;

(iv) Weak – Countries having national publication share in the broad subject below the world average by 5% or more.

Eleven countries such as United States, United Kingdom, Italy, Spain, Canada, Australia, Netherlands, Switzerland, Belgium, Sweden and Brazil share strong to moderately strong similarities in life sciences and health sciences, but they are weak in engineering sciences. Table 6 shows similarities in their research profiles by subject (Table 6).

Table 6: Countries Sharing Strong to Moderately Strong Research Profile in Life Sciences and Health Sciences

Countries	Strong	Moderately Strong	Moderately Weak	Weak
United States	Life Sciences	Health Sciences	Physical Science	Engineering Sciences
Australia, Canada, Sweden & Belgium	Life Sciences	Health Sciences, Physical Sciences		Engineering Sciences
Netherlands	Life Sciences, Health Sciences	Physical Sciences		Engineering Sciences
United Kingdom	Life Sciences, Health Sciences		Physical Science	Engineering Sciences
Brazil, Switzerland	Life Sciences, Physical Sciences	Health Sciences		Engineering Sciences
Italy, Spain	Health Sciences, Physical Sciences	Life Sciences		Engineering Sciences

Four countries such as Japan, Germany, France and Poland share strong to moderately strong similarities in life sciences and physical sciences, but they are weak in engineering sciences. Table 7 shows similarities in their research profiles by subject (Table 7).

Table 7: Countries Sharing Strong to Moderately Strong Research Profile in Physical Sciences and Life Sciences

Countries	Strong	Moderately Strong	Moderate Weak	Weak
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Germany	Physical Sciences	Life Sciences, Health Sciences		Engineering Sciences
Japan	Physical Sciences	Life Sciences, Engineering Sciences	Health Sciences	
France	Physical Sciences	Life Sciences	Health Sciences, Engineering Sciences	
Poland	Physical Sciences	Life Sciences	Engineering Sciences	Health Sciences

Five countries such as Russia, China, India, South Korea and Taiwan share strong to moderately strong similarities in physical sciences and engineering sciences, but they are weak in health sciences. Table 8 shows similarities in their research profiles by subject (Table 8).

Table 8: Countries Sharing Strong to Moderately Strong Research Profile in Physical Sciences and Engineering Sciences

Countries	Strong	Moderately Strong	Moderate Weak	Weak
China, Taiwan, Russia	Engineering Sciences, Physical Sciences			Life Sciences Health Sciences
South Korea	Engineering Sciences, Physical Sciences		Life Sciences	Health Sciences
India	Physical Sciences, Life Sciences	Engineering Sciences		Health Sciences

Subject Profile of India in Science and Technology

As per publications output data for 1997-2007, India's research profile by broad disciplines emerges as follows. Physical science subjects together contributed the highest publication share (41.07%), followed by life sciences (29.68%), engineering sciences (29.59%), and health sciences (22.06%) in cumulative national publication output of India during 1997-07 (Table 9).

India's subject profile is quite different from that of China, South Korea, and Brazil. For example, compared to India, China and South Korea each contributed the highest publication share (51.60% and 50.18 %) in engineering, followed by 38.97 % and 38.75 % in physical sciences, 15.12% and 23.33% in life sciences , and 11.25% and 14.81% in health sciences during similar period. In contrast, Brazil

Materials Science	38748	7551	15111	12.00	11.51	12.44	0.93
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Table 11: Select Developing Countries Share in National Output in Most Productive Subject Categories

Subjects	Percentage Share of National Output, 1997-2007			
	India	China	Brazil	South Korea
Medicine	19.15	11.05	27.26	13.83
Chemistry	15.96	10.98	9.07	10.95
Physics	14.22	15.71	14.98	19.06
Agricultural & Biological Sciences	13.33	4.69	15.31	4.57
Engineering	13.12	29.86	10.02	25.41
Biochemistry, Genetics & Molecular Biology	12.77	8.74	13.92	15.91
Materials Sciences	12.00	14.63	7.19	16.58

Comparative Publications Share of Developing Countries: In comparison to India, China contributed larger share in engineering, physics and materials science (29.86%, 15.71% and 14.63%) and so also South Korea (25.41%, 19.06% and 16.58%). India's national publications share in these subjects were (13.12%, 14.22% and 12.0%) and Brazil (10.02%, 14.98% and 7.19%) in its cumulative national publication output during 1997-07 (Table 11). In contrast, comparatively larger publication share was devoted to medicine, chemistry and agricultural & biological sciences by Brazil (27.26%, 9.07% and 15.31%) and India (19.15%, 15.96% and 13.33%) compared to China (11.05%, 10.98% and 4.69%) and South Korea (13.83%, 10.95% and 4.57%) in cumulative national publication output during 1997-07. Larger national publication share in biochemistry, genetics & molecular biology was devoted by South Korea (15.91%) and Brazil (13.92%) as against India (12.77%) and China (8.74%) during 1997-07 (Table 11).

Share of International Collaborative Publications by Subject: The share of international collaborative publications in cumulative national subject publication output in India in most productive subject areas during 1997-07 was highest in physics (27.84%), followed by biochemistry, genetics & molecular biology (19.51%), materials science (17.29%), engineering (14.38%), chemistry (13.75%), agricultural & biological sciences (11.87%) and medicine (11.14%). India witnessed increase in its share of international collaborative publications by 5.30% (from 13.59% to 18.89%) in its publications output in materials science from 1997-99 to 2005-07, followed by 4.31% (from 8.97% to 13.28%) in medicine, 3.44% (from 10.46% to 13.90%) in agricultural & biological sciences, 2.28% (from 13.09% to 15.23%) in biochemistry, genetics & molecular biology, 2.14% (from 13.09% to 15.23%) in chemistry, 1.40% (from 27.28% to 28.68%) in physics and 1.12% (from 16.21% to 17.33%) in engineering (Table 12).

Table 12: Most Productive Subject Areas- International Collaboration Share

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Subject	International Collaborative Research Output			International Collaborative Research Output (%)			
	1997-07	1997-99	2005-07	1997-07	1997-99	2005-07	Difference 1997-99 to 2005-07
Medicine	6890	975	3268	11.14	8.97	13.28	4.31
Chemistry	7091	1354	2917	13.75	13.09	15.23	2.14
Physics	12789	2702	4958	27.84	27.28	28.68	1.40
Agricultural & Biological Sciences	5108	998	2057	11.87	10.46	13.90	3.44
Engineering	6092	1356	2901	14.38	16.21	17.33	1.12
Biochemistry, Genetics & Molecular Biology	8049	1546	3906	19.51	20.17	22.45	2.28
Materials Sciences	6699	1026	2854	17.29	13.59	18.89	5.30

Comparative Global Publications Share by Subject: The global publication share of India, China, Brazil, and South Korea in most productive subject areas during 1997-2007 was differing. It was 4.57% in chemistry in India, compared to 9.67% by China, 1.56% by Brazil and 2.49% by South Korea. In agricultural & biological sciences, it was 4.05% by India compared to 4.38% by China, 2.80% by Brazil and 1.10% by South Korea. In materials science, it was 3.41% by India compared to 12.80% by China, 1.23% by Brazil and 3.75% by South Korea. In physics, it was 2.73% by India compared to 9.28% by China, 1.73% by Brazil and 2.91% by South Korea. In biochemistry, genetics & molecular biology, it was 2.11% by India compared to 4.43% by China, 1.38% by Brazil and 2.09% by South Korea. In engineering, it was 1.69% by India compared to 11.86% by China, 0.78% by Brazil and 2.61% by South Korea. In medicine, it was 1.48% by India compared to 2.62% by China, 1.26% by Brazil and 0.85% by South Korea (Table 13).

India's global publication share has increased by 1.89% (from 3.73% to 5.62%) in chemistry, followed by 1.24% (from 1.62% to 2.86%) in biochemistry, genetics & molecular biology, 1.17% (from 3.10% to 4.27%) in materials science, 0.78% (from 3.60% to 4.38%) in agricultural & biological sciences, 0.71% (from 2.61% to 3.32%) in physics, 0.75% (from 1.01% to 1.76%) in medicine and 0.32% (from 1.71% to 2.03%) in engineering from the year 1997 to the year 2007 (Table 13).

Table 13: Most Productive Subject Areas- Global Publication Share of India, China and Brazil

Subject	India			China		
	1997	2007	1997-07	1997	2007	1997-07
Medicine	1.01	1.76	1.48	0.72	4.39	2.62

Chemistry	3.73	5.62	4.57	5.22	14.55	9.67
Physics	2.61	3.32	2.73	5.17	16.16	9.28
Agricultural & Biological Sciences	3.60	4.38	4.05	1.44	8.18	4.38
Engineering	1.71	2.03	1.69	5.18	22.57	11.86
Biochemistry, Genetics & Molecular Biology	1.62	2.86	2.11	1.57	9.33	4.43
Materials Sciences	3.10	4.27	3.41	7.09	21.42	12.80

Subjects	Brazil			South Korea		
	1997	2007	1997-07	1997	2007	1997-07
Medicine	0.81	1.71	1.26	0.42	1.28	0.85
Chemistry	1.16	1.92	1.56	1.75	3.17	2.49
Physics	1.54	1.79	1.73	1.76	3.64	2.91
Agricultural & Biological Sciences	1.95	3.76	2.80	0.57	1.71	1.10
Engineering	0.70	0.78	0.78	1.99	2.88	2.61
Biochemistry, Genetics & Molecular Biology	0.85	1.76	1.38	1.15	2.76	2.09
Materials Sciences	0.85	1.27	1.23	2.55	5.51	3.75

Medium Productivity Subject Areas of Research in India

Earth & planetary sciences, environmental sciences, pharmacology, toxicology & pharmaceuticals, chemical engineering, mathematics, immunology & microbiology, veterinary sciences and computer science are the medium productive subjective areas of Indian research, each contributing between 2.65% to 6.36% share in the cumulative publication output by India during 1997-2007. The national publication share of India witnessed increase in some of these subjects from 1997-99 to 2005-07: 1.34% (from 3.09% to 4.43%) in computer science, 0.72% (from 3.42% to 4.14%) in immunology & microbiology, 0.53% (from 6.11% to 6.64%) in pharmacology, toxicology & pharmaceuticals, 0.50% (from 5.93% to 6.43%) in environmental science and 0.23% (from 5.87% to 6.10%) in chemical engineering. The decline in the national publications share was witnessed by 1.33% (from 5.71% to 4.38%) in earth & planetary sciences, 1.0% in veterinary science and 0.15% (from 4.37% to 4.22%) in mathematics from 1997-99 to 2005-07 (Table 14).

Share of International Collaborative Publications by Subject: The share of international collaborative publications in India's cumulative publication output in medium productive subjective areas during 1997-07 was highest in mathematics (27.66%), followed by computer science (23.7%), earth & planetary science

(22.24%), immunology & microbiology (19.36%), chemical engineering (13.73%), environmental sciences (10.8%), pharmacology, toxicology & pharmaceuticals (9.10%) and veterinary science (4.0%). India has witnessed significant rise in international collaborative research output over time (1997-99 to 2005-07) by 6.05% (from 18.97% to 25.02%) in earth & planetary sciences, 3.29% (from 9.84% to 13.14%) in environmental sciences, 2.98% (from 11.90% to 14.88%) in chemical engineering, 2.68% (from 25.86% to 28.18%) in pharmaceuticals, toxicology & pharmaceuticals, 2.51% (from 25.86% to 28.18%) in mathematics, as against decrease by 10.1% (from 31.07% to 20.96%) in computer science and 0.26% (from 20.04% to 19.77%) in immunology & microbiology (Table 16).

Comparative Global Publications Share by Subject: India's global publication share in medium productive subject areas of research during 1997-07 was: (i) 5.36% in India, compared to 0.86% in China, 3.17% in Brazil, and 0.81% in South Korea in veterinary science; (ii) 3.39% in India, compared to 4.50% in China, 1.47% in Brazil, and 1.88% in South Korea in pharmacology, toxicology & pharmaceuticals; (iii) 3.32% in India, compared to 5.12% in China, 1.27% in Brazil, and 1.08% in South Korea in environmental sciences; (iv) 2.77% in India, compared to 9.55% in China, 1.13% in Brazil, and 2.69% in South Korea in chemical engineering; (v) 2.31% in India, compared to 9.57% in China, 1.92% in Brazil, and 2.93% in South Korea in mathematics; (vi) 2.27% in India, compared to 9.11% in China, 1.18% in Brazil and 0.85% in South Korea in earth & planetary sciences; (vii) 2.22% in India, compared to 2.25% in China, 2.25% in Brazil and 2.08% in South Korea in immunology & microbiology; and (viii) 1.49% in India, compared to 10.31% in China and 0.99% in Brazil and 3.45% in South Korea in computer science (Table 17).

India's global publication share has increased by 2.47% (from 2.62% to 5.09%) in pharmacology, toxicology & pharmaceuticals, 1.74% (from 1.55% to 3.29%) in immunology & microbiology, 1.25% (from 2.67% to 3.92%) in environmental science, 0.75% (from 3.23% to 3.98%) in chemical engineering, and 0.24% (from 1.66% to 1.90%) in computer science, and against decreased by 0.13% (from 5.41% to 5.28%) in veterinary science from the year 1997 to 2007 (Table 17).

Comparative Publications Share of Developing Countries: India accounts for highest publication share (6.37%, 6.25% and 2.65%) among select four developing countries in environmental sciences, pharmacology, toxicology & pharmaceuticals and veterinary sciences. In contrast, earth & planetary sciences and immunology & microbiology account for second highest, chemical engineering the third highest, and other subjects namely mathematics and computer science the lowest publication share among the four developing countries during 1997-07. China accounts for highest national publication share(6.30%) only in earth & planetary sciences, second highest (6.55% and 7.87%) in computer science and chemical engineering, third highest (3.19% and 5.70%) in environmental sciences and mathematics, and lowest (2.69%, 1.26% and 0.14%) in pharmacology, toxicology & pharmaceuticals, immunology& microbiology, and veterinary sciences during 1997-07 among the select four Asian countries..

In comparison, Brazil devoted highest national publication share to immunology & microbiology (6.48%), second highest (4.05%, 4.50%, 5.86% and 2.61%) to environmental sciences, pharmacology, toxicology & pharmaceuticals, mathematics and veterinary sciences, third highest (4.17% and 3.86%) to earth & planetary sciences and computer science, and lowest to(3.98%) to chemical engineering during 1997-07 among the select four developing countries. South Korea accounts for highest national publication share (7.14%, 6.75% and 10.17%) in chemical engineering, mathematics and computer science, second highest (4.51%) to immunology & microbiology, third highest (4.35% and 0.50%) in pharmacology, toxicology & pharmaceuticals, and veterinary sciences, and lowest (2.28% and 2.61%) in earth & planetary sciences and environmental sciences during 1997-07 among select four Asian countries (Table 15).

Table 14: Medium Productivity Subject Areas – National Publication Statistics

Subject	Research Output			Publication Share (%)		
	1997-07	1997-99	2005-07	1997-07	1997-99	2005-07
Earth & Planetary Science	15588	3748	5323	4.83	5.71	4.38
Environmental Science	20556	3891	7811	6.36	5.93	6.43
Pharmacology	20177	4009	8067	6.25	6.11	6.64
Chemical Engineering	18869	3850	7415	5.84	5.87	6.10
Mathematics	13683	2869	5132	4.24	4.37	4.22
Immunology & Microbiology	12048	2241	5027	3.73	3.42	4.14
Computer Science	11270	2028	5381	3.49	3.09	4.43
Veterinary Science	8558	2065	2615	2.65	3.15	2.15

Table 15: Select Developing Countries Publication Share in National Output in Medium Productive Subject Categories

Subjects	Percentage Share of National Publication Output, 1997-2007			
	India	China	Brazil	South Korea
Earth & Planetary Science	4.83	6.30	4.17	2.28
Environmental Science	6.37	3.19	4.05	2.61
Pharmacology, Toxicology & Pharmaceutics	6.25	2.69	4.50	4.35
Chemical Engineering	5.84	6.55	3.98	7.14
Mathematics	4.24	5.70	5.86	6.75
Immunology & Microbiology	3.73	1.26	6.48	4.51
Computer Science	3.49	7.87	3.86	10.17
Veterinary Science	2.65	0.14	2.61	0.50

Table 16: Medium Productive Subject Areas- International Collaboration statistics

Subject	International Collaborative Research Output	International Collaborative

				Research Output (%)			
	97-07	97-99	2005-07	97-07	97-99	2005-07	Difference 97-99 to 05-07
Earth & Planetary Science	3466	711	1332	22.24	18.97	25.02	6.05
Environmental Science	2220	383	1026	10.80	9.84	13.14	3.29
Pharmacology, Toxicology & Pharmaceutics	1836	304	828	9.10	7.58	10.26	2.68
Chemical Engineering	2590	458	1103	13.73	11.90	14.88	2.98
Mathematics	3785	742	1446	27.66	25.86	28.18	2.31
Immunology & Microbiology	2332	449	994	19.36	20.04	19.77	-0.26
Computer Science	2671	630	1128	23.70	31.07	20.96	-10.10
Veterinary Science	342	58	139	4.00	2.81	5.32	2.51

Table 17: Medium Productivity Subject Areas- Global Publication Share of India, China and Brazil

Subject	Global Publication Share (%)					
	India			China		
	1997	2007	1997-07	1997	2007	1997-07
Earth & Planetary Science	2.42	2.47	2.27	3.04	16.21	9.11
Environmental Science	2.67	3.92	3.32	1.94	9.69	5.12
Pharmacology, Toxicology & Pharmaceutics	2.62	5.09	3.39	2.09	8.01	4.50
Chemical Engineering	3.23	3.98	2.77	5.33	19.20	9.55
Mathematics	2.67	2.18	2.31	4.36	16.29	9.57
Immunology & Microbiology	1.55	3.29	2.22	0.77	5.31	2.25
Computer Science	1.66	1.90	1.49	2.56	18.29	10.31
Veterinary Science	5.41	5.28	5.36	0.37	2.18	0.86

Subject	Global Publication Share (%)					
	Brazil			South Korea		
	1997	2007	1997-07	1997	2007	1997-07
Earth & Planetary Science	1.05	1.31	1.18	0.49	1.18	0.85
Environmental Science	0.87	1.73	1.27	0.59	1.41	1.08
Pharmacology, Toxicology & Pharmaceutics	1.00	2.18	1.47	1.24	2.39	1.88
Chemical Engineering	1.02	1.47	1.13	1.83	3.96	2.69
Mathematics	1.61	1.67	1.92	1.62	3.47	2.93
Immunology & Microbiology	1.44	3.01	2.25	1.19	2.95	2.08
Computer Science	0.76	1.03	0.99	2.54	3.57	3.45
Veterinary Science	2.61	4.25	3.17	0.31	1.93	0.81

Low Productivity Subject Areas of Research in India

Energy and neurology are the two low productive subject areas contributing publications share between 1.33% and 1.84% in cumulative publication output by India during 1997-07. The national publication share in India witnessed an increase by 0.15% (from 1.20% to 1.35%) in neurology and decrease by 0.22% (from 2.09% to 1.87%) in energy from 1997-99 to 2005-07 (Table 18).

Comparative Publications Share of Developing Countries: Neurology has contributed large share in Brazil (3.73%) and South Korea (1.87%) compared to India (1.33%) and China (0.72%) during 1997-07. In contrast, energy contributed larger share in South Korea (1.88%) and China (3.29%), compared to India (1.84%) and Brazil (1.39%) during 1997-07 (Table 19).

Share of International Collaborative Publications by Subject: The share of international collaborative publications in India's cumulative national publications output in these low productive subject areas during 1997-07 was 16.34% in neurology and 16.27% in energy. India has witnessed a significant rise in international collaborative publications of 6.29% (from 12.98% to 19.27%) in neurology as against decrease of 1.08% (from 15.88% to 14.79%) in energy from 1997-99 to 2005-07 (Table 20).

Comparative Global Publications Share by Subject: India's global publication share in these two subject areas are : (i) 0.91% in India compared to 13.91% in China, 13.99% in Brazil and 9.30% in South Korea in neurology and (ii) 2.02% in India, compared to 11.1% in China, 0.92% in Brazil and 1.64% in South Korea in energy. India's global publication share has increased by 0.92% (from 0.61% to 1.53%) in neurology and decreased by 0.34% (from 2.92% to 2.58%) in energy from the year 1997 to 2007 (Table 21).

Table 18: Low Productivity Subject Areas – National Publication Statistics

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Subject	Research Output			Publication Share (%)		
	1997-07	1997-99	2005-07	1997-07	1997-99	2005-07
Neurology	4285	786	1635	1.33	1.20	1.35
Energy	5938	1373	2278	1.84	2.09	1.87

Table 19: Select Developing Countries Share in National Output in Low Productive Subject Categories

Subjects	Percentage Share of National Output, 1997-2007			
	India	China	Brazil	South Korea
Neurology	1.33	0.72	3.73	1.87
Energy	1.84	3.29	1.39	1.88

Table 20: Low Productive Subject Areas- International Collaboration Statistics

Subject	International Collaborative Research Output			International Collaborative Research Output (%)			
	1997-07	1997-99	2005-07	1997-07	1997-99	2005-07	Difference 97-99 to 05-07
Neurology	700	102	315	16.34	12.98	19.27	6.29
Energy	966	218	337	16.27	15.88	14.79	-1.08

Table 21: Medium Productivity Subject Areas- Global Publication Share of India, China and Brazil

Subject	Global Publication Share (%)					
	India			China		
	1997	2007	1997-07	1997	2007	1997-07
Neurology	0.61	1.53	0.91	0.67	3.51	13.91
Energy	2.92	2.58	2.02	6.26	20.34	11.10

Subject	Brazil	South Korea

	1997	2007	1997-07	1997	2007	1997-07
Neurology	0.86	2.63	13.99	0.36	1.96	9.30
Energy	0.75	1.02	0.92	1.34	2.09	1.64

Least Productive Subject Areas in India

Public health nursing and dentistry are the least productive Indian subject area contributing each less than 1% publication share in cumulative publication output during 1997-07. India's publication share has increased by 0.35% (from 0.21% to 0.56%) in dentistry, 0.23% (from 0.40% to 0.63) in public health and by 0.20% (from 0.09% to 0.29%) in nursing from 1997-99 to 2005-07 (Table 22).

Comparative Publications Share of Developing Countries: Nursing and public health contributed comparative largest share in South Korea (1.05% and 2.02%) and India (0.30% and 73%) as against china (0.55% and 0.65%) and Brazil (0.44% and 0.56%) during 1997-07. In contrast, dentistry find largest share in Brazil (5.19%) and India (1.36%) compared to South Korea (1.06%) and China (0.92%) during 1997-07 (Table 23).

Share of International Collaborative Publications by Subject: The share of international collaborative publications in India's cumulative national publication output in three least productive subject areas during 1997-07 was highest in nursing (25.04%), followed by public health (16.67%) and dentistry (6.54%). The India's international collaborative publications share has increased by 5.53% (from 13.69% to 19.22%) in public health and by 2.98% (from 23.73% to 26.70%) in nursing, as against decrease by 6.96% (from 12.50% to 5.54%) in dentistry from 1997-99 to 2005-07 (Table 24).

Comparative Global Publications Share by Subject: India's global publication share in least productive subject areas of research during 1997-07 was: (i) 0.73% in India, compared to 0.65% in China, 0.56% in Brazil, and 1.42% in South Korea in public health; (ii) 1.36% in India, compared to 0.92% in China, 5.19% in Brazil and 1.06% in South Korea in dentistry and (iii) 0.30% in India, compared to 0.55% in China, 0.44% in Brazil and 0.38% in South Korea in nursing (Table 25).

Table 22: Least Productivity Subject Areas – National Publication Statistics

Subject	Research Output			Publication Share (%)		
	1997-07	1997-99	2005-07	1997-07	1997-99	2005-07
Public Health	1752	263	765	0.54	0.40	0.63
Dentistry	1132	136	686	0.35	0.21	0.56
Nursing	607	59	352	0.19	0.09	0.29

Table 23: Select Developing Countries Share in National Output in Least Productive Subject Categories

Subjects	Percentage Share of National Output, 1997-2007
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	India	China	Brazil	South Korea
Public Health	0.54	0.16	0.70	1.33
Dentistry	0.35	0.08	2.23	0.34
Nursing	0.19	0.11	0.46	0.29

Table 24: Least Productive Subject Areas- International Collaboration Statistics

Subject	International Collaborative Research Output			International Collaborative Research Output (%)			
	1997-07	1997-99	2005-07	1997-07	1997-99	2005-07	Difference 97-99 to 05-07
Public Health	292	36	147	16.67	13.69	19.22	5.53
Dentistry	74	17	38	6.54	12.50	5.54	-6.96
Nurs	152	14	94	25.04	23.73	26.70	2.98

Table 25: Least Productivity Subject Areas- Global Publication Share of India, China and Brazil

Subject	India			China		
	1997	2007	1997-07	1997	2007	1997-07
Public Health	0.45	1.07	0.73	0.24	1.14	0.65
Dentistry	0.82	2.66	1.36	0.48	1.86	0.92
Nursing	0.11	0.48	0.30	0.14	1.39	0.55

Subject	Brazil			South Korea		
	1997	2007	1997-07	1997	2007	1997-07
Public Health	0.20	1.16	0.56	0.71	2.02	1.42
Dentistry	1.25	9.11	5.19	0.23	1.51	1.06
Nursing	0.08	1.09	0.44	0.05	1.05	0.38

Conclusion

Based on analysis of publications output data for India for 1997-07 it is seen that India's scientific activity is on the rise; it is growing at an average rate of 7.76% per annum. However, despite the significant rise in its average growth rate, India's global share for 1997-07 is still very small (2.11%) compared to leading world economies especially China. China's global share to S&T has shown significant rise from 2.76% in 1997 to 11.51% in 2007 with its average share of 6.50% for 1997-07.

India ranked at 12th position among the top 20 productive countries in the world in science and technology, as seen from world publications output data for 1997-07. India's world share for 1997-07 was 2.11%. The other countries in the top 20 list that contributed world publications share similar to that of India (in the range 2.0% to 2.50%) are Russia, Spain, and Australia. The United States continues to top the list of 20 productive world countries with its global publication share of 23.44% for 1997-07. China ranked at 5th position. The top countries like United Kingdom, Japan, China, Germany, and France contributed world share in the range 4.5% to 7.5%.

The developed and developing countries differ significantly in their annual average publication growth rates in science and technology. Whereas the developed world countries have shown their growth rate averaging between 0% and 5%, the developing countries on the contrary have shown growth comparatively at higher rates, in the range 5% to 20%.

India has shown close similarity in S&T research with countries like Russia, China, South Korea and Taiwan, which have shown, like India, strong emphasis in physical and engineering sciences, but are weak in health sciences.

Physical science is the top priority area of S&T research in India, followed by life sciences, engineering sciences and health sciences. Compared to world average output figures by subject, India's national publications share in physical sciences, life sciences, and engineering sciences each has been above the global average. But in health sciences its share has been below the global average in the discipline. This demonstrates India's strength and weakness in different disciplines. The policy makers in science and technology needs to ponder over and decide for the future the R&D priorities that India needs to pursue to lead India as a knowledge economy by 2020

Medicine, chemistry, physics, agricultural & biological sciences, engineering, biochemistry, genetics & molecular biology and the materials science are the leading most productive subject areas of research in India. India's national publications share in these subject areas was between 12.00% and 19.15% of the cumulative publication output by country during 1997-07. Earth & planetary sciences, environmental science, pharmacology, toxicology & pharmaceuticals, chemical engineering, mathematics, immunology & microbiology, vet science and computer science are the nine medium productive subject areas of research, each contributing between 3.14% to 6.30% share to the cumulative publication output by India during 1997-07. Energy and neurology are the two low productivity subject areas of India contributing share between 1.33% and 1.84% in cumulative publication output during 1997-07.

India's national publications share from 1997-99 to 2005-07 has increased in 14 out of 20 S&T subjects. The largest increase of 3.68% (from 16.57% to 20.25%) in national publication share from 1997-99 to 2005-07 has been observed in medicine, followed by biochemistry, genetics & molecular biology, computer science and engineering (from 1.03% to 2.63%), materials science, immunology & microbiology, pharmacology, toxicology & pharmaceuticals, environmental science, chemical

engineering, public health, nursing and neurology (from 0.15% to 0.93%). In contrast, the largest decrease of 2.37% in national publication share from 1975-99 to 2005-07 was observed in agricultural & biological sciences, followed by earth & planetary sciences and veterinary science, physics, energy and mathematics (from 0.15% to 0.87%).

In terms of global publication share in 20 broad subject areas during 1997-2007, the largest share (5.36%) is accounted by veterinary science, followed by chemistry (4.57%), agricultural & biological sciences (4.05%), materials science (3.41%), pharmacology, toxicology & pharmaceuticals (3.39%), chemical engineering (2.77%), environmental science (3.32%), physics (2.73%), mathematics (2.31%), earth & planetary sciences (2.27%), physics (9.28%), immunology & microbiology (2.22%), biochemistry, genetics & molecular biology (2.11%), energy (2.02%), engineering (1.69%), computer science (1.49%), medicine (1.48%), dentistry (1.36%), neurology (0.91%), public health (0.73%) and nursing (0.30%).

India has improved its global publication share in 16 broad subjects out of 20 from the year 1997 to the year 2007, but the largest increase (1.89%) is achieved by chemistry, followed by dentistry, immunology & microbiology, environmental science, biochemistry, genetics & molecular biology and materials science (from 1.17% to 1.84%), neurology, agricultural & biological sciences, chemical engineering, medicine, physics, and public health (from 0.50% to 0.99%), engineering, nursing, computer science and earth & planetary sciences (from 0.05% to 0.42%). In contrast, the largest decrease in India's global publication share (1.19%) from the year 1997 to the year 2007 was observed by pharmacology, toxicology & immunology, followed by 0.49% in mathematics, 0.34% in energy and 0.13% in veterinary science.

Among the S&T fields, the largest share (28%) of international collaborative papers during 1997-2007 was in mathematics, followed by physics (27.5%), computer science (25.77%), nursing (23.15%), earth & planetary sciences (21.37%), biochemistry, genetics and molecular biology (19.12%), immunology & microbiology (18.88%), materials science (17.04%), energy (16.1%), neurology (15.93%), public health (15.46%), and engineering (14.40%). The largest increase (6.29%) in international collaborative share from 1997-99 to 2005-07 has taken place in neurology, followed by earth & planetary sciences (6.05%), public health (5.53%), materials science (5.30%), medicine (4.31%), agricultural & biological sciences (3.44%), environmental science (3.29%), nursing (2.98%), chemical engineering (2.98%), pharmacology, toxicology & pharmaceuticals (2.68%), veterinary science (2.51%), mathematics (2.31%), biochemistry, genetics & molecular biology (2.28%), chemistry (2.14%), etc. On other hand, the largest decrease (10.10%) in international collaborative papers share from 1997-99 to 2005-07 has taken place in computer science, followed by dentistry (6.96%), energy (1.08%), and immunology & microbiology (0.26%).

It is concluded that compared to other countries like China, South Korea and Brazil, India has to substantially improve its publication output and quality. For this, investment in R&D has to be substantially increased and quality of R&D manpower improved. For improving the quality, international collaboration, which is very low compared to other similarly placed countries, has to be substantially enhanced. The quality of courses has been improved and ongoing teachers training courses has been designed in such a way so that they can stay in touch with latest developments in the field.

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