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Mapping of Indian Publications in S&T: A Scientometric Analysis of Publications in *Science Citation Index*

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ABSTRACT

This paper attempts to analyse the growth and development of science and technology (S&T) activities in India, as reflected in publication output covered by *Science Citation Index* (SCI) during 1990-2004. The Indian scientists published a total of 1,82,111 papers in SCI covered journals during the above period. The present study analyses the broad features of Indian S&T by focusing on its publication growth characteristics, language, format and media of communication, research quality, institutional productivity, patterns of research collaboration, and broad and narrow subject areas of interests of Indian institutions and scientists. A broad comparison of India's research output with select countries, particularly with China, has also been made.

Keywords: S&T, SCI, scientorometric, S&T publications, mapping

1. INTRODUCTION

India has a long and distinguished tradition in science. The scientific thought and innovative ideas relating to the technology have been the part of Indian culture and the basis of its civilization throughout the history going back to the Indus valley civilization. Since then, there have been many great discoveries and technical achievements in India. It was, however, only after independence and through vision and wholehearted support of India's first Prime Minister Jawaharlal Nehru that science and technology (S&T) was developed in a conscious way as a major force for social and economic change in the country. As a result of the efforts since independence, the country has achieved a high degree of self-reliance in several areas.

The development of S&T as a means to meet vital needs is now accepted as a major planning objective. Expenditure on scientific research has gone up substantially from the

first plan (1951-56) to the tenth plan. The central government account for major portion (around 70-75 per cent) of the total expenditure on S&T. The total annual expenditure on S&T is now close to 0.8 per cent of the gross national product (GNP). There has been a significant expansion in the education sector. India's R&D infrastructure at present is made up of more than 300 universities, 400 research laboratories, 10 academic institutes of national importance, and 1300 in-house industrial R&D units. Besides, several other government departments, private, international and non-profitable institutions are also engaged in R&D.

The major R&D agencies/departments like Department of Atomic Energy (DAE), Department of Biotechnology (DBT), Department of Ocean Development (DOD), Department of Electronics (DoE), Department of Space (DoS), Defense Research and Development Organization (DRDO), Department of Science and Technology (DST), Council of Scientific and Industrial Research (CSIR), Indian Council of Agriculture Research (ICAR), and Indian Council of Medical Research (ICMR) account for major share of research funding. The main objectives of these R&D agencies/ departments are to support and coordinate research in their respective areas.

The research is carried out through a chain of research laboratories/research institutes under them as well as through research grants/sponsored projects to higher education sectors, national laboratories and establishments. The academic institutes of national importance like Indian Institute of Science, and Indian Institutes of Technology (IITs) also play a major role in carrying out R&D activities in the country.

Evaluation is one of the key components of any R&D activity. One well-known productivity indicator of the R&D is the number of publications produced by the scientists, institutions and the country. Analysis of publications provide some insight into the complex dynamics of research activity and enables policy makers and science administrators in framing policies and directions in which R&D has to be conducted.

2. LITERATURE REVIEW

Very few studies are available, which attempt to make assessment of Indian science in respect of science publications. Eugene Garfield[1] carried out the first major analysis of world research output, with particular reference to third world science publications in 1973, using SCI database and their citations received from 1973 to 1978. India and Argentina were the only two developing countries ranked 8th with 7888 papers and 15515 citations, and 25th with 1526 papers and 4110 citations, respectively finding place among top 25 countries. Out of the 353000 articles indexed in the 1973 SCI file, only 16000 articles were authored from the 93 third world countries.

India accounted for half of all the articles from the developing countries. Raghuram and Madhavi[2] highlighted the decline in Indian science in their letter published in *Nature* by analysing Indian contributions in the journals indexed in SCI during 1980-1995. According to them, India has not kept pace with the growth in world science output. India's publications output was over 13100 papers in 1981, which declined by 15 per cent by 1995, whereas the world's annual output increased by 24 per cent during the same period. India's share in world output was 2.5 per cent in 1981, which dropped to 1.58 per cent in 1995; its world rank dropped from 8th to 13th during the corresponding period. The concern for decline in Indian science, was raised by Arunachalam[3] in his letter, "Is science in India on the decline", published in *Current Science*. He noted that in 1980, India accounted for 14983 papers in SCI, which had fallen to 12127 papers by 2000.

It was observed that India's publication output was steady over two decades and reached an equilibrium position, whereas output of other developing countries showed an appreciable upward trend. Mehrotra and Lancaster[4] analysed different features of Indian science using 38000 research publications produced in India during 1979 to June 1981. Another study was undertaken by Arunachalam, et al.[5] based on the analyses of more than

42000 papers published by Indian scientists in 2300 journals indexed in SCI during 1989-1992.

Garg and Dutt[6] analysed 12156 papers published by Indian scientists during 1987. Basu and Nagpaul[7] made a bibliometric assessment of Indian science based on the SCI for 1990 and 1994. Kademani, et al.[8] analysed 55313 papers published by Indian nuclear scientists during 1970-2002 based on INIS database. Kademani, et al.[9] made a scientometric assessment of thorium research in India. India ranked second among other countries based on INIS database during 1970-2004. Kademani, et al.[10] also made the assessment of thorium research based on SCI for 1982-2004 and similar results were obtained. There are a few bibliometric studies also on Indian research in different domains[11-14].

3. OBJECTIVES

The main objectives of the paper are to analyse Indian S&T output in terms of its broad characteristics, quality of its research output, characteristics of high productivity institutions, nature of collaboration, broad and narrow subject areas of emphasis, and comparison of India's research output with select developed and developing countries.

4. MATERIALS AND METHODS

Publications data was collected from the SCI (1990-2004) published by the Institute of Scientific Information, Philadelphia (now a division of the Thomson Corporation). A total of 1,82,111 publications records from Indian scientists and institutions were downloaded and analysed as per objectives of the study.

5. RESULTS AND DISCUSSION

5.1 Broad Characteristics of Publications Output

5.1.1 Publications Growth in S&T and its Comparison with Select Countries

The cumulative publication productivity of top 10 countries involved in S&T during 1990-2004 is given in Fig. 1. Among these countries, the US topped the list with 3898821 publications, followed by Japan (916260), England (835732), Germany (796060), France (607697), Canada (469965), Italy (4134934), Russia (413934), Spain (2608851), Australia (258285), the Netherlands (257491), Peoples Republic of China (253170), Sweden (196112), Switzerland (182990), and India (182111). China ranked 12th and India ranked 15th in terms of publication output during 1990-2004.

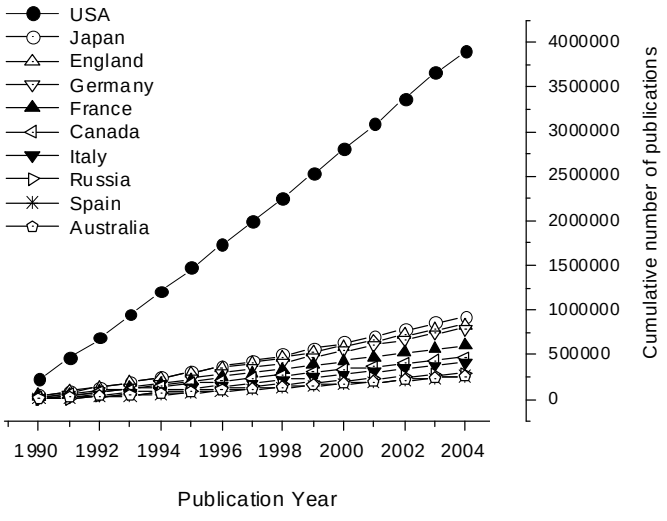

Figure 1. Cumulative publication produtivity of top 10 countries.

China had only 6407 publications compared to India's 10113 publications in 1990. However, China's publication productivity grew tremendously and surpassed India's contribution by 1038 publications in 1997; 2811 publications in 1998; 5002 publications in 1999; 10342 publications in 2000; 12866 publications in 2001; 14833 publications in 2002; 20765 publications in 2003; and 22212 publications in 2004 (Fig. 2).

During these 15 years (1990-2004), India produced 182111 publications with highest, 15414 publications, in 2003; average number of publications per year was 12140. India's publications output witnessed average annual growth rate of 3.05 per cent compared to 13.58 per cent of China during 1990-2004. Compared to India and China, the annual average growth rate of publications during 1990-2004 in Spain was 7.33 per cent, followed by Italy (5.06 per cent), Japan (2.84 per cent), France (2.37 per cent), Canada (1.78 per cent), England (1.45 per cent), and the US (0.81 per cent).

On considering the five-year cumulative growth of publications during 1990-94 to 1995-99, India witnessed a growth rate of 6.63 per cent compared to 73.99 per cent of China during the corresponding period. Similarly, India witnessed a growth rate of 21 per cent

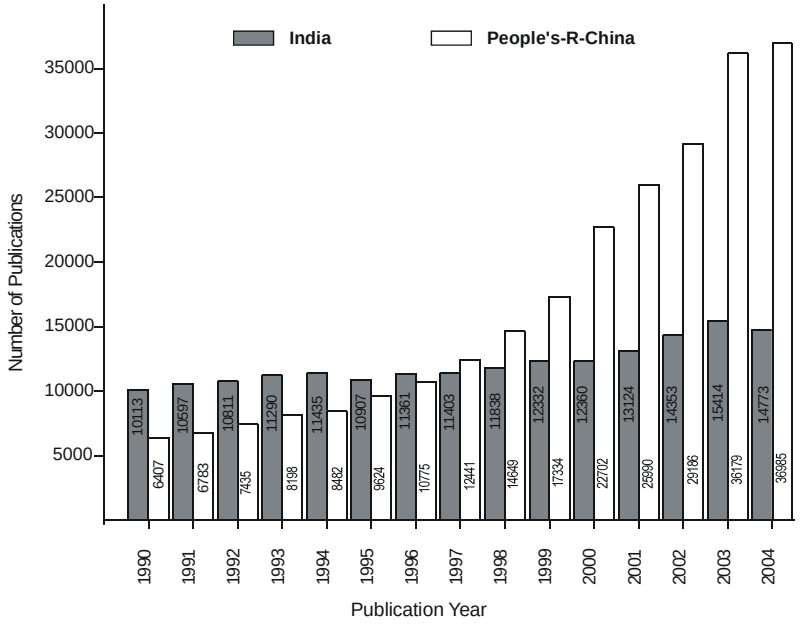

Figure 2. Annual publication output of Indian and China during 1990-2004.

Table 1. Five-year cumulative growth of publications in India and China during 1990-2004

Period	India	China	Growth rate of India's publications (1995-99 to 2000-04)	Growth rate of China's publications (1995-99 to 2000-04)
1990-94	54246	37255	-	-
1995-99	57841	64823	6.63	73.99
2000-04	70024	151042	21.04	133.01
Total	182111	253170	-	-

during 1995-99 to 2000-04, compared to 133.01 per cent of China during the corresponding period (Table 1).

5.1.2 Language, Format and Channels of Communication

On analysing the language of communication used by Indian scientists, English was found to be on top of the list with 1,82,017 (99.94 per cent) publications followed by French (23), Russian (23), German (21), Chinese (11), Romanian (6), Spanish (6), Danish (2), Italian (1), and multilingual (1). Indian scientists contributed their research publications predominantly in English with only a few exceptions. The publications in other foreign languages were mainly due to collaboration with respective foreign institutions.

The Indian scientists communicated their research results in variety of communication formats (Table 2). More than 85 per cent of the Indian S&T research was published as journal articles, followed by notes (4.47 per cent), letters (3.87 per cent), meeting-abstracts (2.48 per cent), etc. The total Indian publications in S&T were published in over 3895 journals. The maximum number of publications (6848 papers) appeared in *Current Science*, followed by *Indian Journal of Chemistry-Section B* (3566 papers), *Indian Journal of Chemistry-Section A* (3272 papers), *Pramana–Journal of Physics* (1904 papers), etc.

Table 3 gives the list of top 50 productive journals preferred by the Indian scientists for publication. These 50 top journals together contributed 50,968 papers, which constitute 25.53 per cent of the total Indian publications output in S&T during 1990-2004. Of these 50 journals, the first 15 journals contributed 28,406 papers (14.78 per cent), next 15 journals 11,374 papers (5.93 per cent), and next 20 journals 11, 188 papers (with 5.82 per cent) in the country cumulative output.

Table 2. Indian publications output by type of format of communication

Type of format	India's publication output during following periods			
	1990-94	1995-99	2000-04	1990-2004
Articles	42952	50714	62364	156030
Notes	6856	1299	0	8155
Letters	2221	2280	2553	7054
Meeting-Abstracts	870	1528	2121	4519
Reviews	669	973	1533	3175
Editorial-Materials	409	648	995	2052
Corrections	42	162	228	432
Biographical-Items	59	89	108	256
Discussions	152	47	0	199
News-Items	0	80	100	180
Reprints	12	16	14	42
Book-Reviews	1	3	5	9
Software-Reviews	3	2	1	6
Bibliography	0	0	2	2
Total	54246	57841	70024	182111

Table 3. Major journals preferred by the Indian scientists for publication

S. No.	Journal title	Country	Number of publications
1.	*Current Science*	India	6848
2.	*Indian Journal Of Chemistry Section B*	India	3566
3.	*Indian Journal Of Chemistry Section A*	India	3272
4.	*Pramana-Journal Of Physics*	India	1904
5.	*Tetrahedron Letters*	England	1745
6.	*Journal Of Applied Polymer Science*	United States	1741
7.	*Physical Review B*	USA	1670
8.	*Synthetic Communications*	USA	1158
9.	*Physical Review D*	USA	1054
10.	*Physics Letters B*	Netherlands	963
11.	*Journal Of Materials Science Letters*	Netherlands	960
12.	*Journal Of Applied Physics*	USA	946
13.	*Indian Journal Of Medical Research*	India	913
14.	*Solid State Communications*	USA	835
15.	*Journal Of Materials Science*	Netherlands	831
16.	*Physical Review A*	USA	827
17.	*Tetrahedron*	England	824
18.	*Chemical Physics Letters*	Netherlands	816
19.	*Physical Review Letters*	USA	799
20.	*Proc of the Indian Academy of Sci-Che Sci*	India	797
21.	*Acta Crystallographica Section C*	Denmark	796
22.	*Synthesis and Reactivity in Inorganic and Metal*	USA	795
23.	*Physical Review E*	USA	749
24.	*Physical Review C*	USA	741
25.	*Materials Letters*	Netherlands	727
26.	*National Medical Journal of India*	India	710
27.	*Journal of Physics-Condensed Matter*	England	706
28.	*Journal of Chemical Physics*	USA	701
29.	*Polyhedron*	England	696
30.	*Journal of Biosciences*	India	690
31.	*Journal of Chemical Research-S*	England	689
32.	*Phytochemistry*	England	679
33.	*Physics Letters A*	Netherlands	669
34.	*Abst of Pap of the Ame Chemical Society*	USA	666
35.	*Transition Metal Chemistry*	Netherlands	635
36.	*Physica C-Superconductivity and Its Applications*	Netherlands	611
37.	*Bulletin of Envi Contamination and Toxi*	USA	596
38.	*Materials Chemistry and Physics*	Switzerland	587
39.	*Physica B-Condensed Matter*	Netherlands	584
40.	*Astrophysics and Space Science*	Netherlands	539
41.	*Journal of Sound and Vibration*	USA	527
42.	*Biochemical and Biophysical Res Comm*	USA	521
43.	*Spectrochimica Acta Part A*	England	520
44.	*Astrophysical Journal*	USA	502
45.	*Journal of Organic Chemistry*	USA	498
46.	*Crystal Research and Technology*	Germany	486
47.	*Journal of Ethnopharmacology*	Ireland	479
48.	*Thin Solid Films*	Netherlands	474
49.	*Lancet*	England	464
50.	*Nuclear Inst and Meth In Phy Res Sec B*	Netherlands	462

5.2 Quality of Research Output

Around 92.33 per cent of the total Indian publications in S&T during 1990-2004 were published in the journals with impact factors (IF) ranging from 0.01 to 35.04, and around 7.67 per cent in journals having zero IF.

A significantly large number of publications (67.50 per cent) appeared in low-impact journals (IF = 0.01 to 2.0), 22.92 per cent in medium impact journals (IF = 2.01 to 4.0), and only 7.55 per cent in high impact journals (IF > 4). On studying the increase in quality of papers during 1990-94 to 2000-04, it was found that while the share of papers in zero IF journals substantially reduced from 15.21 per cent to 2.03 per cent, the share of papers published in medium and high IF journals increased from 14.80 per cent to 22.92 per cent and from 5.34 per cent to 7.54 per cent, respectively, showing improvement in the quality of Indian research with time (Table 4).

5.3 Broad and Narrow Subject Area of Publications

On classifying the total Indian publications output in S&T under 11 broad subjects during 1990-2004, it was observed that maximum number of publications were in chemistry (40640), followed by physics (37822), basic life sciences (15797), engineering (14679), clinical medicine (14763), earth and environmental sciences (8027), multidisciplinary sciences (7771), biology (7700), agricultural sciences (6,300), mathematics (2247), and social sciences (329). A broad distribution of Indian S&T publications classified under 168 sub-fields under 11 broad subjects is given in *Appendix I.* The research output in these 168 sub-fields varied from 1 to 10800 papers. Of these total sub-fields, 49 sub-fields together contributed 79.23 per cent of the total papers. On further classifying these 49 sub-fields on the basis of output, the first two sub-fields contributed 21162 papers (11.62 per cent), the next four sub-fields contributed 29928 publications (16.43 per cent), the next five sub-fields contributed 24786 publications (13.61 per cent), the next 113 sub-fields contributed 34491 publications (18.93 per cent), and the next 25 sub-fields contributed 33949 publications (18.64 per cent).

On further consolidating various sub-fields under broad subjects, it was found that Indian scientists had published 40640 papers in chemistry during 1990-2004, which were spread out across 9 sub-fields, with maximum number (10800) of papers in multidisciplinary chemistry followed by organic chemistry (10362), physical chemistry (5931), polymer science (4796), inorganic and nuclear chemistry (4422), analytical chemistry (2066), medicinal chemistry (1073), electrochemistry (763), and applied chemistry (427). Similarly 37822 papers were published by Indian scientists in physics during 1990-2004, which were spread out in 14 sub-fields, with maximum number of papers in multidisciplinary physics (7112) followed by condensed matter physics (6938), atomic, molecular and chemical physics (3900), astronomy and astrophysics (3459), applied physics (3432), crystallography (2566), nuclear physics (2370), optics (1717), fluids and plasma physics (1661), particle physics (1322), spectroscopy (1254), mathematical physics (924), acoustics (808), and thermodynamics (359) (Table 5). In mathematics, Indian scholars published 2247 publications

Table 4. Distribution of Indian S&T papers according to IF

Impact factor category	IF range	Percentage share of papers during			
		1990-94	1995-99	2000-04	1990-04
Without IF	0.00 – 0.00	15.21	7.43	2.03	7.67
Low IF	0.01 – 2.00	64.65	66.72	67.51	66.41
Medium IF	2.01 – 4.00	14.80	18.64	22.92	19.14
High IF	> 4	5.34	7.21	7.54	6.78
Total		100.0	100.0	100.0	100.00
Total Papers		54251	57838	700022	182111

with maximum (991) number in applied mathematics followed by general mathematics (919), statistics and probability (270), and mathematics with interdisciplinary applications (67) (*Annexture I*).

In earth and environmental sciences, Indian scientists published 8027 publications during 1990-2004, which were spread out across 13 sub-fields with maximum number (2014) of papers in environmental sciences, followed by multidisciplinary geosciences (1666), water resources (1103), geochemistry and geophysics (844), meteorology and atmospheric physics (665), remote sensing (450), ecology (425), mineralogy (296), oceanography (223), geology (198), paleontology (122), imaging science (13), and limnology (8) (*Annexture I*).

In basic life sciences, Indian scientists published 15797 papers during 1990-2004, with maximum number (5307) of papers in biochemistry and molecular biology followed by biotechnology and applied microbiology (2548), genetics and heredity (2018), microbiology (1875), cell biology (1490), public-environmental and occupational health (609), reproductive biology (455), biophysics (430), biochemical research methods (378), development biology (328), etc. (*Annexture I*).

Similarly, in biology total papers published were 7700 with maximum (4330) number in plant sciences followed by general biology (1344), mycology (535), marine and freshwater biology (492), zoology (475), entomology (428), biodiversity conservation (79), and ornithology (17). In agriculture, total papers published were 6300 with maximum (1192) number in food science and technology followed by multidisciplinary agriculture (1114), veterinary sciences (812), agronomy (794), nutrition and dietetics (662), soil science (649), dairy and animal science (312), horticulture (295), fisheries (277), forestry (177), and agricultural economics and policy (16).

In biomedical sciences, Indian scientists contributed 23967 publications, which were spread out across 16 sub-fields with maximum number (3151) of papers in pharmacology and pharmacy followed by research and experimental medicine (2407), oncology (1580), neurosciences (1078), radiology and nuclear medicine (1025), immunology (983), toxicology (863), infectious diseases (767), tropical medicine (623), parasitology (445), etc. In clinical medicine, Indian scientists published 14763 papers, which were spread out across 28 sub-fields with maximum number (1992) of papers in general and internal medicine, followed by cardiac and cardiovascular systems (1380), ophthalmology (1196), surgery (1078), pediatrics (1077), gastroenterology and hepatology (1052), endocrinology and metabolism (951), dermatology (925), urology and nephrology (675), clinical neurology (667), hematology (627), obstetrics and gynecology (606), psychiatry (545), etc. (*Annexture I*).

Indian scientists published 14679 publications in engineering during 1990-2004, which were spread out across 26 sub-fields. The maximum number (9721) of publications were in materials science, which accounted for more than 40 per cent of the total output in engineering. The medium productive sub-fields were chemical engineering (2344 publications), electrical and electronics engineering (2216 publications), nuclear science and technology (1953 publications), metallurgy and metallurgical engineering (1465 publications), mechanics (1177 publications), and energy and fuels (1085 publications). Rest of the 19 sub-fields made low contribution, with maximum number (756 papers) in mechanical engineering followed by multidisciplinary engineering (577), instruments and instrumentation (515), aerospace engineering (268), environmental engineering (246), geological engineering (227), telecommunications (174), civil engineering (159), operational research and management (150), etc.

Similarly Indian scientists had published 2069 papers in computer sciences during 1990-2004, which were spread out across 8 sub-fields with maximum number (590) of papers in theory and methods followed by interdisciplinary applications (492), artificial intelligence (350), information systems (173), automation and control systems (128), cybernetics (116), software engineering (115), and hardware and architecture (105).

5.4 Nature of collaboration

On analysing the extent of collaboration in S&T output during 1990-2004, it was found that only 10 per cent publications (18224) involved single authors and 90 per cent publications (163887) involved multi-authors indicating very large collaborative output from Indian scientists.

Over the years, the multi-authored collaborative papers increased from 48236 (with 88.93 per cent share) to 63847 papers (with 91.17 per cent share). Among the multi-authored collaborative papers, the share of two-authored papers decreased from 39.68 per cent (19143 papers) during 1990-94 to 28.96 per cent (18492 papers) during 2000-04, while the share pf papers involving more than two authors increased from 60.32 per cent (29,3 papers) to 71.04 per cent (45355 papers) during the corresponding period (Tables 5 and 6) .

Out of 182111 publications published in the country during 1990-2004, only 31186 (17.12 per cent) involved international collaboration. India's international collaborative share of papers in country's total output increased from 12.55 per cent to 21.11 per cent during 1990-94 to 2000-04. In overall, compared to the growth rate of 29.06 per cent of Indian research output during 1990-94 to 2000-04, the growth rate in international collaborative publications output was 117.16 per cent during the corresponding period (Table 7).

Table 5. Growth of single authored and multi-authored papers in India

Period	Total papers	Single authored	Multiauthored
1999-94	54236	6010	48236
1995-99	57841	6037	51804
2000-04	70024	6177	63847
1990-04	182111	18224	163887

Table 6. Growth of collaborative papers in India

Number of authors	Number of collaborative papers during			
	1990-94	1995-99	2000-04	1990-04
2	19143	18142	18492	55777
3-5	25921	28409	36438	90768
6-10	2918	4585	7796	15299
11-50	176	440	796	1412
51-255	78	228	325	631
Total	48236	51804	63847	163887

Table 7. Growth in India's total papers and international collaborative papers

Period	Total papers	Total ICP	Share of ICP
1990-94	54246	6806	12.55
1995-99	57841	9600	16.60
2000-04	70024	14780	21.11
1990-04	182111	31186	17.12

Of the India's total international collaborative papers (ICP), 24896 (79.83 per cent) involved bilateral collaboration and the remaining 6278 (20.17 per cent) multilateral collaboration. A substantial growth in both bilateral and multilateral collaborative papers research output of India was observed over the years. The bilateral collaborative research output increased from 5759 in 1990-94 to 14780 papers in 2000-04, showing a growth rate of 98.82 per cent. But in terms of total international collaborative papers, the share of India's bilateral collaborative papers decreased from 84.61 per cent to 77.47 per cent during the corresponding period. The multilateral collaborative output increased from 1047 to 3330 papers during 1990-94 to 2000-04, showing a growth rate of 218 per cent. But in terms of total collaborative papers output of the country, the share of multilateral collaborative papers increased from 15.39 per cent to 22.53 per cent during the corresponding period (Table 8).One hundred sixty-seven countries were involved in international collaboration with India during 1990-2004. Among the multilateral collaborative research output, the number of countries participating varied from 3 to 30 per paper (Table 9).

It was observed that the maximum number of international collaborative papers (11869) were with the US during 1990-2004. Among European countries, India's largest number of collaborative papers were with Germany (4640) followed by England (3202), France (2669), Italy (1741), Russia (1012), Switzerland (1004), Netherlands (970), Spain (832), Sweden (611), Poland (536), Hungary (510), Belgium (458), Scotland (410), Finland (330), Bulgaria (320), Denmark (314), Austria (304), Romania (266), Wales (250), Cyprus (236), Czech Republic (206), North Ireland (184), Norway (153), Ireland (139), Slovenia (124), and Portugal (104) during this period.

Among Asian countries during 1990-2004, India's largest number of collaborative papers were with Japan (2988) followed by China (1153), South Korea (892), Taiwan (756), Malaysia (321), Israel (315), Singapore (307), Bangladesh (254), Philippines (184), Thailand (141), Iran (102), Nepal (85), Saudi Arabia (85), Pakistan (78), Kuwait (75), Hong Kong (71), Vietnam (65), Indonesia (61), and Sri Lanka (46). Among Oceania countries, India's largest number of collaborative papers were with Australia (1092) followed by New Zealand (138). Among Latin America countries, India's largest number of collaborative papers were with Brazil (596) followed by Mexico (386), Argentina (193), Colombia (167), Chile (120), Ecuador (68), Venezuela 31), Cuba (26), and Peru (20). Among African countries, India's largest number of collaborative papers were with South Africa (220) followed by Egypt (109), Nigeria (75), Kenya (65), Niger (27), and Ethiopia (23). India's largest number of collaborative papers with various institutes

Table 8. Growth in India's International Collaborative Papers

Period	ICP		
	Bilateral	Multilateral	Total
1990-94	5759	1047	6806
1995-99	7687	1915	9602
2000-04	11450	3328	14778
1990-04	24896	6280	31186

Table 9. Growth in India's multilateral collaborative papers

Number of countries participating	Number of collaborative papers during			
	1990-94	1995-99	2000-04	1990-04
3-5	923	1546	2760	5229
6-10	61	190	211	462
11-30	63	179	357	599
Total	1047	1915	3328	6281

during 1990-2004 were with Istituto Nazionale di Fisica Nucleare, Italy (1909 publications) followed by University of Maryland, USA (533); Rheinisch-Westfalische Technische Hochschule (Aachen), Germany (529); University of Michigan, USA (502); etc.

5.5 Most Productive Indian R&D Institutions

Eleven thousand five hundred fifty-five Indian organisations published 182111 research papers in S&T during 1990-2004. Of these 35 organisations published more than 1100 publications. On cumulating individual productivity of institutions, the 10 Indian institutions contributed 49936 papers (27.42 per cent of national share), 20 institutions 78557 papers (43.14 per cent share), 30 institutions 92893 papers (51.79 per cent share), and 35 institutions 100562 papers (55.22 per cent share). Thus, the productivity of Indian research output was highly concentrated with only 35 institutions, which contributed more than 55 per cent share in national output in S&T. The largest number of publications (10247) were contributed by Indian Institute of Science, Bangalore followed by Bhabha Atomic Research Centre, Mumbai (6782); Tata Institute of Fundamental Research, Mumbai (5132); Banaras Hindu University, Varanasi (4487); All India Institute of Medical Sciences, New Delhi (4201); Indian Institute of Technology, Kharagpur (3957); University of Delhi, Delhi (3902); and National Chemical Laboratory, Pune (3813). Among the top 35 Indian productive institutions, 11 were research institutes, 10 were academic institutions of national importance and 14 universities and colleges. Analyses of the growth and decline in publication productivity using normalised activity index of the research institutes, showed that only eight institutes out of 11 witnessed rise in their activity index during 1990-94 to 2000-04 (Table 10).

Analyses of the growth and decline in publication productivity using normalised activity index of 10 academic institutes of national importance, showed that only four institutes (IIT Chennai, New Delhi, Roorkee, and PGIMER, Chandigarh) witnessed decline and the rest six institutions witnessed rise in their activity index during 1990-94 to 2000-04 (Table 11). The same analysis of the universities and colleges found that five universities (University of Delhi, Panjab University, Anna University, Christian Medical College, and Sanjay Gandhi Post Graduate Institute of Medical Sciences) out of 15 witnessed rise in their activity index during 1990-94 to 2000-04 (Table 12).

Table 10. Publication productivity and activity index of top research institutes

Institute Name	Number of Papers				Activity Index		
	90-94	95-99	00-04	90-04	90-94	95-99	00-04
BARC, Mumbai	2043	2087	2652	6782	1.011	0.969	1.017
TIFR, Mumbai	1401	1741	1990	5132	0.916	1.068	1.008
NCL, Pune	1007	1283	1523	3813	0.887	1.059	1.039
IACS, Kolkata	882	1219	1177	3278	0.903	1.171	0.934
IICT, Hyderabad	715	818	1452	2985	0.804	0.863	1.265
SINP, Kolkata	468	749	801	2018	0.779	1.169	1.032
CDRI, Luchnow	568	533	498	1599	1.193	1.049	0.81
IGCAR, Kalpakkam	348	489	620	1457	0.802	1.057	1.107
NPL, New Delhi	531	482	435	1448	1.231	1.048	0.781
PRL, Ahmedabad	364	519	558	1441	0.848	1.134	1.007
JNCASR, Bangalore	118	387	756	1261	0.314	0.966	1.559
Total papers in respective year blocks	54246	57841	70024	182111	-	-	-

Table 11. Publication productivity and activity index of top academic institutes of India

Institute name	Number of Papers				Activity Index		
	1990-94	1995-99	2000-04	1990-2004	1990-94	1995-99	2000-04
Indian Institute of Science, Bangalore	2875	3322	4050	10247	0.942	1.021	1.028
All India Institute of Medical Sciences New Delhi	1026	1361	1814	4201	0.82	1.02	1.123
Indian Institute of Technology Kharagpur	1112	1221	1624	3957	0.943	0.972	1.067
Indian Institute of Technology, Chennai	1180	1369	1184	3733	1.061	1.155	0.825
Indian Institute of Technology, Kanpur	1041	1203	1438	3682	0.949	1.029	1.016
Indian Institute of Technology New Delhi	1163	1127	1389	3679	1.061	0.964	0.982
Indian Institute of Technology, Mumbai	962	1202	1497	3661	0.882	1.034	1.063
Post Graduate Institute of Medical Research, Chandigarh	799	770	980	2549	1.052	0.951	1.000
Indian Institute of Technology, Roorkee	502	500	404	1506	1.119	1.045	0.697
Indian Statistical Institute, Kolkata	322	501	607	1430	0.756	1.103	1.104
Total papers in respective year blocks	54246	57841	70024	182111	-	-	-

Table 12. Publication productivity and activity index of top universities and colleges

Institute Name	Number of Papers				Activity Index		
	1990-94	1995-99	2000-04	1990-2004	1990-94	1995-99	2000-04
Banaras Hindu University, Varanasi	1662	1530	1295	4487	1.243	1.074	0.751
University of Delhi, Delhi	1152	1255	1495	3902	0.991	1.013	0.996
Jadavpur University, Kolkata	931	911	1099	2941	1.063	0.975	0.972
Panjab University, Chandigarh	783	865	1030	2678	0.982	1.017	1.000
University of Kolkata, Kolkata	858	771	709	2338	1.232	1.038	0.789
University of Hyderabad, Hyderabad	730	808	782	2320	1.056	1.097	0.877
University of Madras, Chennai	634	774	784	2192	0.971	1.112	0.930
Aligarh Muslim University, Aligarh	560	479	572	1611	1.167	0.936	0.923
Osmania University, Hyderabad	658	506	442	1606	1.375	0.992	0.716
Anna University, Chennai	308	521	765	1594	0.649	1.029	1.248
Jawaharlal Nehru University, Delhi	487	491	589	1567	1.043	0.987	0.978
Christian Medical College, Vellore	359	442	504	1305	0.920	1.067	1.000
University of Rajasthan, Jaipur	504	322	439	1265	1.338	0.801	0.903
Sanjay Gandhi Postgraduate Institute of Medical Sciences Lucknow	233	402	535	1170	0.690	1.080	1.190
Total papers in respective year blocks	54246	57841	70024	182111	-	-	-

6. CONCLUSION

The paper analysed the contribution (182111 papers) by the Indian scientists covered in SCI during last 15 years (1990-2004). During this period, India achieved an average annual growth rate of 3.05 per cent of its publications output, which is much less than China (13.58 per cent), but comparable to many developed countries such as Japan (2.84 per cent), France (2.37 per cent). In all, 11555 Indian organisations were involved in these publications, and the top 10 institutes published 27.42 per cent of total publications. Bhabha Atomic Research Centre (BARC), Mumbai, topped the list among research institutes with 6782 publications. Indian Institute of Science, Bangalore, ranked first among academic institutes of national importance with 10247 publications, and Banaras Hindu University, Varanasi, appeared on the top among universities and colleges with 4487 publications. The quality of Indian research output as reflected in IF per paper has improved with time. The share of papers published in medium and high impact journals increased from 14.80 per cent and 5.34 per cent during 1990-94 to 22.92 per cent and 7.54 per cent during 2000-04, respectively. The share of international collaborative papers in total output increased substantially, rising from 12.55 per cent during 1990-94 to 21.11 per cent during 2000-04. The maximum numbers of India's collaborative papers were with the US. The major fields of publications during 1990-04 were chemistry followed by physics, basic life sciences, engineering and clinical medicine.

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Annexure I

Indian Scientific Research Concentrated in various Microdomains

S. No.	Micro-domains	Publications		Total publications	Percentage	
		Domestic	International collaborative		Domestic	International
1.	Acoustics	761	47	808	94.180	5.820
2.	Agricultural Economics & Policy	5	11	16	31.250	68.750
3.	Agricultural Engineering	72	28	100	72.000	28.000
4.	Agriculture, Dairy & Animal Science	279	33	312	89.420	10.580
5.	Agriculture, Multidisciplinary	990	124	1114	88.870	11.130
6.	Agriculture, Soil Science	496	153	649	76.430	23.570
7.	Agronomy	566	228	794	71.280	28.720
8.	Allergy	106	13	119	89.080	10.920
9.	Anatomy & Morphology	153	30	183	83.610	16.390
10.	Andrology	109	16	125	87.200	12.800
11.	Anesthesiology	462	31	493	93.710	6.290
12.	Astronomy & Astrophysics	2193	1266	3459	63.400	36.600
13.	Automation & Control Systems	81	47	128	63.280	36.720
14.	Behavioral Science	45	14	59	76.270	23.730
15.	Biochemical Research Methods	304	74	378	80.420	19.580
16.	Biochemistry & Molecular Biology	4537	770	5307	85.490	14.510
17.	Biodiversity Conservation	67	12	79	84.810	15.190
18.	Biology	1178	166	1344	87.650	12.350
19.	Biophysics	347	83	430	80.700	19.300
20.	Biotechnology & Applied Microbiology	2234	314	2548	87.680	12.320
21.	Cardiac & Cardiovascular Systems	1209	171	1380	87.610	12.390
22.	Cell Biology	1262	228	1490	84.700	15.300
23.	Chemistry, Analytical	1906	160	2066	92.260	7.740
24.	Chemistry, Applied	377	50	427	88.290	11.710
25.	Chemistry, Inorganic & Nuclear	3629	793	4422	82.070	17.930
26.	Chemistry, Medicinal	948	125	1073	88.350	11.650
27.	Chemistry, Multidisciplinary	9559	1241	10800	88.510	11.490
28.	Chemistry, Organic	9507	855	10362	91.750	8.250
29.	Chemistry, Physical	4983	948	5931	84.020	15.980
30.	Clinical, Neurology	593	74	667	88.910	11.090
31.	Computer Science, Artificial Intelligence	258	92	350	73.710	26.290
32.	Computer Science, Cybernetics	89	27	116	76.720	23.280
33.	Computer Science, Hardware & Architecture	64	41	105	60.950	39.050
34.	Computer Science, Information System	127	46	173	73.410	26.590
35.	Computer Science, Interdisciplinary	404	88	492	82.110	17.890
36.	Computer Science, Software Engineering	69	46	115	60.000	40.000
37.	Computer Science, Theory & Method	440	150	590	74.580	25.420
38.	Construction & Building Technology	132	7	139	94.960	5.040
39.	Critical Care Medicine	55	13	68	80.880	19.120
40.	Crystallography	1803	763	2566	70.270	29.730
41.	Dentistry, Oral Surgery & Medicine	175	25	200	87.500	12.500
42.	Dermatology	846	79	925	91.460	8.540
43.	Developmental biology	276	52	328	84.150	15.850
44.	Ecology	323	102	425	76.000	24.000
45.	Education, Scientific Disciplines	14	1	15	93.330	6.670

S. No.	Micro-domains	Publications		Total publications	Percentage	
		Domestic	International collaborative		Domestic	International
46.	Electrochemistry	635	128	763	83.220	16.780
47.	Emergency Medicine	4	0	4	100.000	0.000
48.	Endocrinology & Metabolism	725	226	951	76.240	23.760
49.	Energy & Fuels	957	128	1085	88.200	11.800
50.	Engineering, Aerospace	247	21	268	92.160	7.840
51.	Engineering, Biomedical	61	12	73	83.560	16.440
52.	Engineering, Chemical	2060	284	2344	87.880	12.120
53.	Engineering, Civil	130	29	159	81.760	18.240
54.	Engineering, Electrical & Electronics	1832	384	2216	82.670	17.330
55.	Engineering, Environmental	196	50	246	79.670	20.330
56.	Engineering, Geological	182	45	227	80.180	19.820
57.	Engineering, Industrial	81	6	87	93.100	6.900
58.	Engineering, Manufacturing	80	27	107	74.770	25.230
59.	Engineering, Mechanical	664	92	756	87.830	12.170
60.	Engineering, Multidisciplinary	497	80	577	86.140	13.860
61.	Engineering, Ocean	95	26	121	78.510	21.490
62.	Engineering, Petroleum	0	1	1	0.000	100.000
63.	Entomology	348	80	428	81.310	18.690
64.	Environmental Sciences	1766	248	2014	87.690	12.310
65.	Evolutionary Biology	32	39	71	45.070	54.930
66.	Fisheries	230	47	277	83.030	16.970
67.	Food Science & Technology	1102	90	1192	92.450	7.550
68.	Forestry	135	42	177	76.270	23.730
69.	Gastroenterology & Hematology	935	117	1052	88.880	11.120
70.	Genetics & Heredity	1499	519	2018	74.280	25.720
71.	Geochemistry & Geophysics	595	249	844	70.500	29.500
72.	Geography, Physical	12	5	17	70.590	29.410
73.	Geology	126	72	198	63.640	36.360
74.	Geosciences, Multidisciplinary	1263	403	1666	75.810	24.190
75.	Geriatrics & Gerontology	49	10	59	83.050	16.950
76.	Health Care Sciences & Services	27	30	57	47.370	52.630
77.	Hematology	491	136	627	78.310	21.690
78.	History & Philosophy of Science	8	0	8	100.000	0.000
79.	Horticulture	264	31	295	89.490	10.510
80.	Imaging Science & Photographic Technology	12	1	13	92.310	7.690
81.	Immunology	791	192	983	80.470	19.530
82.	Infectious Disease	520	247	767	67.800	32.200
83.	Instruments & Instrumentation	461	54	515	89.510	10.490
84.	Integrative & Complementary Medicine	12	2	14	85.710	14.290
85.	Limnology	5	3	8	62.500	37.500
86.	Marine & Freshwater Biology	395	97	492	80.280	19.720
87.	Materials Science, Biomaterials	96	14	110	87.270	12.730
88.	Materials Science, Ceramics	456	76	532	85.710	14.290
89.	Materials Science, Characterization	185	18	203	91.130	8.870
90.	Materials Science, Coatings & Films	521	119	640	81.410	18.590

S. No.	Micro-domains	Publications		Total publications	Percentage	
		Domestic	International collaborative		Domestic	International
91.	Materials Science, Composites	104	40	144	72.220	27.780
92.	Materials Science, Multidisciplinary	6750	1357	8107	83.260	16.740
93.	Materials Science, Paper & Wood	56	8	64	87.500	12.500
94.	Materials Science, Textiles	121	3	124	97.580	2.420
95.	Mathematics	612	307	919	66.590	33.410
96.	Mathematics, Applied	722	269	991	72.860	27.140
97.	Mathematics, Interdisciplinary App.	57	10	67	85.070	14.930
98.	Mechanics	998	179	1177	84.790	15.210
99.	Medical Ethics	0	1	1	0.000	100.000
100.	Medical Informatics	51	11	62	82.260	17.740
101.	Medical Laboratory Technology	219	34	253	86.560	13.440
102.	Medicine, General & Internal	1740	252	1992	87.350	12.650
103.	Medicine, Legal	198	14	212	93.400	6.600
104.	Medicine, Research & Experimental	2238	169	2407	92.980	7.020
105.	Metallurgy & Metallurgical Engineering	1190	275	1465	81.230	18.770
106.	Meteorology & Atmospheric Science	539	126	665	81.050	18.950
107.	Microbiology	1494	381	1875	79.680	20.320
108.	Microscopy	113	10	123	91.870	8.130
109.	Mineralogy	193	103	296	65.200	34.800
110.	Mining & Mineral Processing	2	2	4	50.000	50.000
111.	Multidisciplinary Sciences	7185	586	7771	92.460	7.540
112.	Mycology	418	117	535	78.130	21.870
113.	Neuroimaging	72	8	80	90.000	10.000
114.	Neurosciences	865	213	1078	80.240	19.760
115.	Nuclear Science & Technology	1588	365	1953	81.310	18.690
116.	Nutrition & Dietetics	547	115	662	82.630	17.370
117.	Obstetrics & Gynecology	544	62	606	89.770	10.230
118.	Oceanography	174	49	223	78.030	21.970
119.	Oncology	1277	303	1580	80.820	19.180
120.	Operations Research & Management	95	55	150	63.330	36.670
121.	Ophthalmology	878	318	1196	73.410	26.590
122.	Optics	1402	315	1717	81.650	18.350
123.	Ornithology	11	6	17	64.710	35.290
124.	Orthopedics	41	3	44	93.180	6.820
125.	Otorhinolaryngology	184	17	201	91.540	8.460
126.	Paleontology	75	47	122	61.480	38.520
127.	Parasitology	336	109	445	75.510	24.490
128.	Pathology	289	54	343	84.260	15.740
129.	Pediatrics	964	113	1077	89.510	10.490
130.	Peripheral Vascular Disease	120	29	149	80.540	19.460
131.	Pharmacology & Pharmacy	2828	323	3151	89.750	10.250
132.	Physics, Applied	2635	797	3432	76.780	23.220
133.	Physics, Atomic, Molecular, & Chemical	2975	925	3900	76.280	23.720
134.	Physics, Condensed Matter	5391	1547	6938	77.700	22.300
135.	Physics, Fluids & Plasmas	1198	463	1661	72.130	27.870

S. No.	Micro-domains	Publications		Total publications	Percentage	
		Domestic	International collaborative		Domestic	Internationa
136.	Physics, Mathematical	695	229	924	75.220	24.780
137.	Physics, Multidisciplinary	5065	2047	7112	71.220	28.780
138.	Physics, Nuclear	1796	574	2370	75.780	24.220
139.	Physics, Particles fields	686	636	1322	51.890	48.110
140.	Physiology	323	54	377	85.680	14.320
141.	Plant Sciences	3539	791	4330	81.730	18.270
142.	Polymer Science	4396	400	4796	91.660	8.340
143.	Psychiatry	415	130	545	76.150	23.850
144.	Psychology	14	3	17	82.350	17.650
145.	Public, Environmental & Occupational	486	123	609	79.800	20.200
146.	Radiology, Nuclear Medicine & Medical	893	132	1025	87.120	12.880
147.	Rehabilitation	7	1	8	87.500	12.500
148.	Remote Sensing	396	54	450	88.000	12.000
149.	Reproductive Biology	387	68	455	85.050	14.950
150.	Respiratory System	87	14	101	86.140	13.860
151.	Rheumatology	124	22	146	84.930	15.070
152.	Robotics	17	6	23	73.910	26.090
153.	Spectroscopy	1057	197	1254	84.290	15.710
154.	Sport Sciences	6	0	6	100.000	0.000
155.	Statistics & Probability	126	144	270	46.670	53.330
156.	Substance Abuse	18	5	23	78.260	21.740
157.	Surgery	1013	65	1078	93.970	6.030
158.	Telecommunications	127	47	174	72.990	27.010
159.	Thermodynamics	301	58	359	83.840	16.160
160.	Toxicology	779	84	863	90.270	9.730
161.	Transplantation	264	9	273	96.700	3.300
162.	Transportation Science & Technology	18	8	26	69.230	30.770
163.	Tropical Medicine	501	122	623	80.420	19.580
164.	Urology & Nephrology	612	63	675	90.670	9.330
165.	Veterinary Sciences	729	83	812	89.780	10.220
166.	Virology	432	144	576	75.000	25.000
167.	Water Resources	928	175	1103	84.130	15.870
168.	Zoology	384	91	475	80.840	19.160
– 168. Total		150925	31186	182111	82.880	17.120

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