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Mathematics research in India today: What does the literature reveal?

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Mathematics research in India, as reflected by papers indexed in *Mathsci* 1988-1998, is quantified and mapped. Statistics, quantum theory and general topology are the three subfields contributing the most to India's output in mathematics research, followed by special functions, economics and operations research, and relativity and gravitational theory. Indian Statistical Institute and Tata Institute of Fundamental Research are the two leading publishers of research papers. Unlike in many other fields, Calcutta publishes the largest number of papers in mathematics, followed by Mumbai, New Delhi, Chennai and Bangalore. West Bengal, Uttar Pradesh, Maharashtra, Tamil Nadu and Delhi are the leading states. Researchers from 257 institutions spread over 134 cities/towns have published 17,308 papers in the 11 years. About 92% of these papers have appeared in 877 journals published from 62 countries. Journals published in the USA, UK and the Netherlands are popular with Indian mathematicians. Of the 36 journals that have published at least a hundred papers, 20 are Indian journals of which only two are indexed in *Journal Citation Reports*. In all, about 38.5% of papers have been published in Indian journals, as against about 70% in agriculture, 55% in life sciences, 33.5% in medicine and 20% in physics. In the later years, there has been a moderate shift to non-Indian journals. Close to 78% of papers have come from universities and colleges and 13% from the institutions under science related departments. Almost all papers in high impact journals are physics related and most of them have come from institutions under the Department of Atomic Energy. Over 15% of the 9760 papers published during 1993-1998 are internationally coauthored. In all of science, as seen from *Science Citation Index*, 14% of Indian papers were internationally coauthored in 1991 and 17.6% in 1998. The USA, Canada, and Germany are the important collaborating nations, followed by France, Italy, Japan and the UK.

Introduction

I had the privilege of meeting Vassily Vassilievich Nalimov in the United States a few years ago. It was Gene Garfield, who got some of Nalimov's works published in English, who introduced me to this polymath and thinker of the first order. There was something special about this man, an intense calmness born out of years of suffering in labour camps faced with heroic fortitude and years of equally intense thinking of matters philosophical, spiritual and mathematical. While his monumental accomplishments

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made, no doubt, one feel a sense of awe, his friendly disposition made one feel at home in his presence. To pay tribute to him, I chose to look at mathematics research in India, for, among other things, Nalimov has made world class contributions to mathematics, especially in the fields of mathematical statistics and probability theory, and was for ten years an associate of the renowned Russian mathematician Andrei Kolmogorov (who had visited the Indian Statistcal Institute, Calcutta, one of the best-known mathematics research centres in Independent India). Besides, Unesco has declared 2000 the Year of Mathematics.

Mathematics is the basis of modern civilization, although much of the pursuit of mathematics is without any inkling to the real world, says Basil Gordon of the University of California at Los Angeles. Indeed there is something for everybody to gain from the universal language of mathematics. Today it is virtually impossible to do advanced level work in any branch of science or engineering or some areas of economics and social sciences without the application of mathematics.

India has a very long tradition of excellence in mathematics and astronomy, dating back to antiquity. In modern times India has produced much work in both pure and applied mathematics as well as in the related areas of operations research, statistics, computer science and theoretical physics. According to Basil Gordon, Russia and the USA are the top contributors to the literature of mathematics, followed by England, France, Germany and then India and China. The 20th century has transformed mathematics from a cottage industry run by a few semi-amateures into a world-wide industry run by an army of professionals, says Michael Atiyah in his preface to *Mathematics: Frontiers and Perspectives*, brought out by the American Mathematical Society on behalf of the International Mathematical Union as part of the celebration of the Year of Mathematics. A part of the army lives and works in India. Today Indian mathematicians, statisticians and computer scientists are welcome everywhere. Virtually every major university in North America has one or more Indian mathematicians, statisticians or computer scientists on its faculty.

There are a few accounts of mathematics research in 20th century India. Notable among them are those by Varadarajan,[1] Narasimhan[2] and Seshadri,[3] all outstanding mathematicians. They have written from the perspective of professional researchers trying to look at achievements of Indian mathematics, both of individuals and of institutions. In contrast, this paper is written from the perspective of a scientometricician trying to map mathematics research in India by analysing the published literature. There is another difference: While the three eminent mathematicians have covered several decades, I have analysed the research output over a 11-year period.

The words "Indian mathematics" evoke in the minds of most people the images of Ramanujan and the well-known mathematicians of ancient India such as Aryabhatta, Bhaskara and Brahmagupta. But what about more recent times? Narasimhan[2] has chronicled the work of Indian mathematicians in the first half of the Twentieth Century, who under very difficult circumstances kept mathematical traditions alive in India. He singles out Calcutta and Madras as the two most important centres and has paid handsome tributes to K. Anand Rau, R. Vaidyanathaswamy, T. Vijayaraghavan, S. S. Pillai and S. Minakshisundaram of the Madras school, Syamdas Mukhopadhyay, Nikhilranjan Sen, Rabindranath Sen, P. C. Mahalnobis [founder of Indian Statistical Institute (ISI), Calcutta], and R. C. Bose of the Calcutta school, and Komaravolu Chandrasekharan [who founded the school of mathematics at Tata Institute of Fundamental Research (TIFR), Bombay] and C. T. Rajagopal (Ramanujan Institute, Madras). Narasimhan[2] pays glowing tributes to C. P. Ramanujan, "certainly one of the most powerful mathematical minds to emerge in India since the mid-fifties" and "in many ways, a singular figure."

Varadarajan[1] and Seshadri[3] have written brief accounts of mathematics in post-Independent India. Both of them highlight the very important role played by TIFR, largely thanks to the initial leadership of K. Chandrasekharan, and ISI, Calcutta, where C. Radhakrishna Rao played a crucial role. Among those who made a mark in this period are C. P. Ramanujan and V. K. Patodi, both of whom died in the prime of their creative life, C. S. Seshadri, M. S. Narasimhan, M. S. Raghunathan, S. Ramanan, K. Ramachandra (all of TIFR), C. R. Rao, V. S. Varadhan, V. S. Varadarajan (all three now in the USA), K. R. Parthasarathy, and R. Ranga Rao (all of ISI, Calcutta). Mention must also be made of certain foreigners such as the Jesuit priest Fr. Racine of France and F. W. Levi of Germany, both of whom had worked in India and helped many young aspiring Indian mathematicians.

In what follows, I have attempted to map India's contribution to the literature of mathematics and related fields as seen from 11 years (1988-1998) of *Mathsci* database on CD-ROM. I have identified the institutions active in publishing, the journals used and their impact factors, the subfields in which different institutions are active, etc. I have not extended the analysis to the contributions made by individuals. This study is in continuation of a series of studies on mapping India's contribution to different fields such as physics,[4] biology,[5] agriculture,[6] medicine,[7,8] and science as a whole (based on data from *Science Citation Index*).[9]

Methodology

The techniques used for data collection and analysis are largely similar to our earlier studies.[4–9] Bibliographic data on documents originating from Indian institutions were downloaded from the *Mathsci* CD-ROM database, giving "(6-*" as the search command under 'IN' (for institution). This search picks up all entries having an Indian address in the byline irrespective of whether it is the address of the first author, second author or the last author. Unlike with some other bibliographic databases on CD-ROM, downloading such data from *Mathsci* database is simple and straightforward. The fields downloaded are: author, publication year, journal title, language, subject descriptor, document type, institution name, and subfield.

The *Mathsci* database has 61 sections covering such diverse subfields as “History and biography”, “information and communication, circuits”, and “Functions of a complex variable”. Some subfields are closely related to mathematics, such as “Statistics”, “Computer science”, “Astronomy and astrophysics”, “Geophysics”, “Quantum theory”, and “Economics, operations research, programming, games”.

Impact factor values for journals were noted from *Journal Citation Reports* 1997. Not all journals indexed in *Mathsci* are indexed in *Science Citation Index*, and those journals not indexed in SCI are not assigned an impact factor.

The data were analysed using programs generated inhouse using FoxPro, Excel and Access. Also analysed are papers published in the three calendar years 1990, 1994 and 1998.

Analysis

In the eleven years 1988-1998 (CD-ROM disc years and not the years of publication of the papers) *Mathsci* database had indexed 17,308 papers that had at least one Indian address in the byline (Table 1). Of these more than 15,900 (or about 92%) are published in 876 journals (Table 2). Others are non-journal items. In Table 2, impact factor values from JCR 1997 are given wherever available. Close to 99.2% of the papers are in English. *Mathsci* has also indexed 113 Indian papers written in Hindi, 17 in French, five in Russian, four in Chinese(!), one each in Italian and German.

Table 1
Types of documents published by Indian researchers as seen from *Mathsc*i 1988-98

Document type*	1993-98		1988-92		Total	%
	No. of papers	%	No. of papers	%		
Journal	9141	92.00	6760	91.70	15901	91.87
Proceedings-Paper	679	6.80	555	7.50	1234	7.13
Book	90	0.90	56	0.80	146	0.84
Book, Proceedings	22	0.20	0	0.00	22	0.13
Journal, Journal-Translation	5	0.10	0	0.00	5	0.03
	9937	100.0	7371	100.0	17308	100.00

*As recorded in *Mathsci* database

Table 2
Journals used by Indian researchers to publish their work as seen from *Mathsci* 1988-98

Journal	No. of papers		Impact Factor 1997	Publication country	Total	% of journal papers
	1993-98	1988-92				
Indian-J.-Pure-Appl.-Math.	329	323	0.092	IND	652	4.10
Bull.-Calcutta-Math.-Soc.	298	161	0.000	IND	459	2.89
Acta-Cienc.-Indica-Math.	270	35	0.000	IND	305	1.92
Math.-Student	101	202	0.000	IND	303	1.90
J.-Indian-Math.-Soc. (N.S.)	178	106	0.000	IND	284	1.79
Comm.-Statist.-Theory-Methods	140	123	0.194	USA	263	1.65
J.-Phys.-A	148	112	1.480	UKD	260	1.63
Proc.-Indian-Acad.-Sci.-Math.-Sci.	163	75	0.184	IND	238	1.50
J.-Math.-Anal.-Appl.	140	90	0.339	USA	230	1.45
Fuzzy-Sets-and-Systems	148	59	0.346	NLD	207	1.30
Math.-Ed. (Siwan)	108	90	0.000	IND	198	1.24
J.-Math.-Phys.-Sci.	55	123	1.102	IND	178	1.12
Proc.-Nat.-Acad.-Sci.-India-Sect.-A	81	93	0.000	IND	174	1.09
Phys.-Lett.-A	96	75	1.267	NLD	171	1.08
J.-Math.-Phys.	91	79	1.102	USA	170	1.07
Modern-Phys.-Lett.-A	111	57	1.208	SGP	168	1.06
Calcutta-Statist.-Assoc.-Bull.	95	69	0.000	IND	164	1.03
Indian-J.-Math.	84	76	0.000	IND	160	1.01
Ganita	71	89	0.000	IND	160	1.01
Astrophys.-Space-Sci.	31	115	0.338	NLD	146	0.92

Table 2 (continued)

Journal	No. of papers 1993-98	1988-92	Impact Factor 1997	Publication country	Total	% of journal papers
Phys.-Lett.-B	94	50	3.581	NLD	144	0.91
Tamkang-J.-Math.	62	81	0.000	TWN	143	0.90
J.-Statist.-Plann.-Inference	86	49	0.263	NLD	135	0.85
J.-Indian-Acad.-Math.	72	63	0.000	IND	135	0.85
Sankhya-Ser.-A	83	49	0.000	IND	132	0.83
Pure-Appl.-Math.-Sci.	51	79	0.000	IND	130	0.82
Internat.-J.-Math.-Math.-Sci.	62	63	0.000	USA	125	0.79
J.-Indian-Soc.-Agricultural-Statist.	63	61	0.000	IND	124	0.78
Soochow-J.-Math.	76	46	0.000	TWN	122	0.77
Phys.-Rev.-D (3)	69	48	3.420	USA	117	0.74
Statist.-Probab.-Lett.	86	29	0.203	NLD	115	0.72
Sankhya-Ser.-B	50	64	0.000	IND	114	0.72
Vijnana-Parishad-Anusandhan-Patrika	35	78	0.000	IND	113	0.71
J.-Indian-Statist.-Assoc.	50	57	0.000	IND	107	0.67
Internat.-J.-Theoret.-Phys.	41	61	0.448	USA	102	0.64
Pure-Math.-Manuscript	56	44	0.000	IND	100	0.63
Jnanabha	59	39	0.000	IND	98	0.62
Nuclear-Phys.-B	68	29	3.531	NLD	97	0.61
Proc.-Amer.-Math.-Soc.	62	32	0.273	USA	94	0.59
Proc.-Math.-Soc.	78	15	0.000	IND	93	0.58
689 other journals	5105					
549 other journals		3571				
Total journal articles	9146	6760			15906	
Non journal items	791	611			1402	
Total	9937	7371			17308	100.00

Classification by journal title

Thirty-six journals, including 20 Indian journals, have published 100 or more papers from India. Thirty-eight journals, including 16 Indian journals, have published more than 50 papers but less than 100. At the other extreme, 182 journals were used by Indian mathematicians to publish just one paper and 108 journals to publish two papers each in the eleven years. Eighty-nine journals have published three Indian papers. The distribution of papers over journals is shown in Figure 1. *Indian Journal of Pure and*

Applied Mathematics, published by the Indian National Science Academy, New Delhi, tops the list of journals used by Indian mathematicians to publish their work. This is followed by four other Indian journals, viz. *Bulletin of the Calcutta Mathematical Society*, *Acta Ciencia Indica Mathematics*, *Mathematics Student* and *Journal of the Indian Mathematical Society (New Series).* Very few journals have an impact factor greater than one. Of course, unlike in new biology or physics, mathematics journals are usually of low impact. That has largely to do with the referencing habits of mathematicians. Indeed, almost all high impact journals in our data set are physics journals.

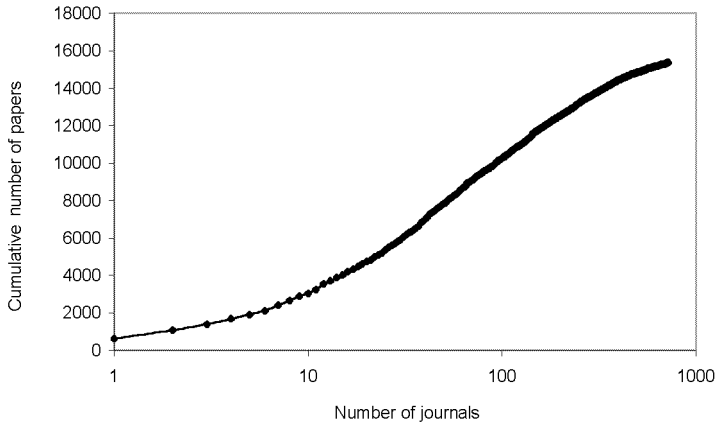

Figure 1. Cumulative number of papers vs. number of journals

The rank order of journals has not remained the same throughout the 11 years. For example, in 1998, while *Indian Journal of Pure and Applied Mathematics* retained its first place, *Journal of Physics A* (GB) moved to the second rank and *Journal of Mathematical Analysis and Applications* (US) to the third. Indeed, of the 17 journals that have carried ten or more Indian papers in 1998, 13 are non-Indian. There has been a shift to foreign journals.

Classification by journal country

Indian researchers have published 9,788 papers (or 61.5% of all journal articles) in 800 non-Indian journals and 6,118 papers (more than 38%) in 77 Indian journals. Only five of the Indian journals are assigned impact factors by JCR 1997: *Current Science*

(0.376; 33 papers), *Indian Journal of Pure and Applied Physics* (0.252; 6 papers), *Proceedings of the Indian Academy of Sciences – Mathematics* (0.184; 238 papers), *Indian Journal of Pure and Applied Mathematics* (0.082; 652 papers), and *National Academy of Sciences Letters* (0.078; 47 papers). In physics, as seen from INSPEC *Physics Abstracts* 1992, about 20% of Indian papers are published in 39 Indian journals.[4] In biology, as seen from *Biological Abstracts* 1992-1994, about 55% of papers from Indian laboratories have appeared in 118 Indian journals.[5] About 70% of Indian papers in agriculture have appeared in Indian journals, as seen from *CAB Abstracts* 1984-1995.[6] In medicine, 33.5% of Indian papers, as seen from *Medline* 1988-1994 have appeared in 30 Indian journals.[7] The vast differences are due to the differences in the communication habits of researchers in different fields and the nature of the fields themselves. The availability of locally published journals and their coverage in international databases also matter.

Table 3
India's contribution to the journal literature of mathematics classified by country of publication of the journals as seen from *Mathsci* 1988-98

Publication country	1993-98			1988-92			Total	%
	No. of journals	No. of papers	%	No. of journals	No. of papers	%		
India	67	3322	36.3	63	2796	41.4	6118	38.5
United States	162	1780	19.5	141	1219	18.0	2999	18.9
Netherlands	62	992	10.8	51	683	10.1	1675	10.5
United Kingdom	68	619	6.8	56	462	6.8	1081	6.8
Germany	37	252	2.8	26	159	2.4	411	2.6
Singapore	16	243	2.7	8	104	1.5	347	2.2
Taiwan	6	196	2.1	5	169	2.5	365	2.3
Switzerland	25	183	2.0	19	77	1.1	260	1.6
Japan	40	175	1.9	34	107	1.6	282	1.8
Italy	23	153	1.7	23	123	1.8	276	1.7
Poland	25	152	1.7	16	97	1.4	249	1.6
Rumania	18	119	1.3	10	54		173	1.1
Hungary	12	96	1.0	12	74	1.1	170	1.1
Canada	11	82		12	86	1.3	168	1.1
Australia	6	78		5	71	1.0	149	0.9
47 Other counteries	150	704		109	471		1175	7.3
Unknown				3	8		8	
Non-journal items		791			611		1402	
Total	728	9937		593	7371		17308	100.00

The 800 non-Indian journals are published from 61 countries (Table 3). Journals published in the USA (2,999 papers), the Netherlands (1,675 papers), and the United Kingdom (1,081 papers) are popular with Indian mathematicians. Indian mathematicians also publish often in journals published in Germany, Singapore, Taiwan, Switzerland, Japan and Italy. Indian researchers have published 95 papers in Chinese journals and 20 papers in Pakistan journals.

Classification by subfield

Of the more than 60 subfields into which *Mathsci* classifies papers it indexes, statistics (62–2,007 papers), quantum theory (81–1,133 papers) and general topology (54–1,038 papers) are the three fields in which Indian researchers have published most often. In seven other subfields, including number theory and differential geometry, Indians have published more than 500 papers in the eleven years but less than 1,000 (Table 4).

Table 4
Indian research papers covered by *Mathsci* 1988-98 classified by subfield

Subfield with code	1993-98		1988-92		Total
	No. of papers	%	No. of papers	%	
62 Statistics	1149 (1)	11.56	858 (1)	11.64	2007
81 Quantum Theory	734 (2)	7.39	399 (2)	5.41	1133
54 General topology	671 (3)	6.75	367 (4)	4.98	1038
33 Special functions	407 (5)	4.10	394 (3)	5.35	801
90 Economics, operations research, programming, games	432 (4)	4.35	357 (5)	4.84	789
83 Relativity and gravitational theory	372 (6)	3.74	345 (6)	4.68	717
30 Functions of a complex variable	333 (7)	3.35	277 (7)	3.76	610
11 Number theory	319 (10)	3.21	259 (8)	3.51	578
47 Operator theory	328 (8)	3.30	221 (11)	3.00	549
53 Differential geometry	301 (11)	3.03	244 (10)	3.31	545
05 Combinatorics	285 (14)	2.87	247 (9)	3.35	532
60 Probability theory and stochastic processes	296 (12)	2.98	189 (12)	2.56	485
68 Computer science	322 (9)	3.24	151 (16)	2.05	473
46 Functional analysis	289 (13)	2.91	177 (13)	2.40	466
76 Fluid mechanics	220 (16)	2.21	169 (15)	2.29	389
16 Associative rings and algebras	227 (15)	2.28	145 (17)	1.97	372
65 Numerical analysis	181 (19)	1.82	136 (19)	1.85	317
35 Partial differential equations	140 (22)	1.41	174 (14)	2.36	314
34 Ordinary differential equations	170 (20)	1.71	138 (18)	1.87	308
20 Group theory and generalizations	198 (17)	1.99	107 (22)	1.45	305
41 other subfields	2563	25.78	2017	27.38	4580
Total	9937	100.00	7371	100.00	17308

In 21 subfields, India's contribution is less than 100 papers. However, these ranks do not hold for each one of the years. For example, statistics holds the first rank in 1990 (157 papers) and 1994 (142 papers), but it is second in 1998 (85 papers), when quantum theory is first with 114 papers. In 1990 quantum theory came fourth with 78 papers and in 1994 third with 97 papers. In both 1990 and 1994, general topology came second.

Classification by journal impact factor

We have classified the 9,146 journal papers indexed in *Mathsci* during the six years 1993-1998 by the impact factor of the journal (as seen from JCR 1997) in Table 5. More than 5,000 papers (nearly 55% of all journal papers) are published in non-SCI journals. (This figure is higher than 47.8% of Indian papers in medicine[7] and 46.4% of Indian papers in biology[5] that have appeared in non-SCI journals.) More than 3,100 papers have appeared in journals whose impact factors are less than unity.

Table 5
Distribution of Indian papers by impact factor of journals

Impact factor range	No. of papers	%
0.000	5019	54.8
>0.0 – 0.5	2638	28.8
>0.5 – 1.0	497	5.4
>1.0 – 1.5	584	6.4
>1.5 – 2.0	120	1.3
>2.0 – 2.5	35	0.4
>2.5 – 3.0	0	
>3.0 – 3.5	69	0.8
>3.5 – 4.0	162	1.8
>4.0 – 4.5	0	
>4.5 – 5.0	0	
>5.0 – 5.5	0	
>5.5 – 6.0	0	
>6.0 – 7.0	17	0.2
>7.0 – 8.0	0	
>8.0	5	0.1
Total	9146	100.0

Source: *Mathsci* 1993-98

At the other extreme, five papers have been published in *Physics Reports* (impact factor 9.099), 17 papers in *Physical Review Letters* (impact factor 6.140), 161 papers in journals whose impact factors are in the range 3.500 - 4.000 and 69 papers in journals in the impact factor range 3.000 – 3.500. All these relatively high impact journals are in the field of physics, e.g. *Physics Letters B* (impact factor 3.581, 94 papers), *Nuclear Physics B* (impact factor 3.531, 68 papers), and *Physical Review D* (impact factor 3.420, 69 papers). This is not surprising as purely mathematical journals do not have high impact factors.

Classification by institution

Although 257 Indian institutions have published papers in mathematics, only six institutions have published more than 500 papers in the eleven years (Table 6). Tata Institute of Fundamental Research, Mumbai, established by Homi Bhabha, is undoubtedly the leading research institution in mathematics in India. It is the only institution to have published more than a thousand papers. Together with its Bangalore centre, TIFR has published 1,261 papers. However, if we add the papers published by the Calcutta, New Delhi, Bangalore and Chennai centres of the Indian Statistical Institute, founded by Mahalanobis, then ISI gets the top position with 1,434 papers. Other institutions leading this table are University of Calcutta, Banaras Hindu University and Indian Institute of Science, Bangalore. Fourteen institutions have published more than 250, but less than 500, papers. These include University of Delhi, five Indian Institutes of Technology, Jadavpur University and the Institute of Mathematical Sciences, Chennai. Twenty-five institutions have published more than 100, but less than 250, papers. At the other extreme, there are 20 institutions that have contributed only one paper, 13 institutions with two papers, 17 institutions with three papers, nine institutions with four papers, seven institutions with five papers, and eight institutions with six papers. Here again, the ranking has not remained the same. For example, ISI, Calcutta, was in the third position in 1990, second in 1994 and first in 1998. TIFR, Mumbai, which held the first rank in 1990 and 1994 slid to second rank in 1998. University of Calcutta which held the second position in 1990 and fourth in 1994 slid to 11th in 1998. A plot of log number of institutions vs. cumulative number of papers is given in Figure 2.

Table 6
Indian institutions publishing papers as seen from *Mathsci* 1988-98

Institution	1993-98		1988-92		Total
	No. of papers	%	No. of papers	%	
Tata Institute of Fundamental Research, Mumbai	678	6.80	485	6.60	1163
Indian Statistical Institute, Calcutta	459	4.60	356	4.80	815
University of Calcutta, Calcutta	427	4.30	278	3.80	705
Banaras Hindu University, Varanasi	255	2.60	330	4.50	585
Indian Institute of Science, Bangalore	341	3.40	185	2.50	526
Indian Statistical Institute, Delhi	322	3.20	150	2.00	472
University of Delhi, New Delhi	254	2.60	182	2.50	436
Indian Institute of Technology, Kanpur	205	2.10	204	2.80	409
Indian Institute of Technology, Kharagpur	266	2.70	139	1.90	405
Indian Institute of Technology, Chennai	263	2.60	134	1.80	397
Jadavpur University, Calcutta	208	2.10	160	2.20	368
Institute of Mathematical Sciences, Chennai	235	2.40	126	1.70	361
Indian Institute of Technology, New Delhi	156	1.60	180	2.40	336
Aligarh Muslim University, Aligarh	181	1.80	146	2.00	327
University of Madras, Chennai	204	2.10	115	1.60	319
Indian Institute of Technology, Mumbai	182	1.80	133	1.80	315
Lucknow University, Lucknow	170	1.70	110	1.50	280
Panjab University, Chandigarh	162	1.60	106	1.40	268
University of Kalyani, Kalyani	165	1.70	96	1.30	261
University of Poona, Pune	153	1.50	87	1.20	240
Marathwada University, Aurangabad	99	1.00	109	1.50	208
Dr. Hari Singh Gour University, Sagar	130	1.30	61	0.80	191
University of Roorkee, Roorkee	100	1.00	77	1.00	177
Andhra University, Waltair	60	0.60	115	1.60	175
University of Gorakhpur, Gorakhpur	55	0.60	112	1.50	167
University of Rajasthan, Jaipur	62	0.60	102	1.40	164
Institute of Physics, Bhubaneswar	111	1.10	47	0.60	158
Indian Statistical Institute, Bangalore	119	1.20	24	0.30	143
Burdwan University, Burdwan	89	0.90	49	0.70	138
Karnatak University, Dharwad	65	0.70	68	0.90	133

Table 6 (continued)

Institution	1993-98		1988-92		Total
	No. of papers	%	No. of papers	%	
University of Jammu, Jammu	95	1.00	35	0.50	130
Saha Institute of Nuclear Physics, Calcutta	81	0.80	47	0.60	128
University of Mysore, Mysore	78	0.80	49	0.70	127
Vikram University, Ujjain	75	0.80	48	0.60	123
Utkal University, Bhubaneswar	82	0.80	41	0.60	123
Cochin University of Science and Technology	90	0.90	31	0.40	121
University of Hyderabad, Hyderabad	73	0.70	46	0.60	119
Sardar Patel University, Vallabh Vidyanagar	76	0.80	41	0.60	117
University of Allahabad, Allahabad	66	0.70	50	0.70	116
Kalyan Mahavidhyalaya, Bhilainagar	83	0.80	32	0.40	115
University of Bombay, Mumbai	48	0.50	64	0.90	112
University of Jodhpur, Jodhpur	63	0.60	45	0.60	108
Jawaharlal Nehru University, New Delhi	59	0.60	46	0.60	105
214 other institutions	2615	46.8	2330	49.70	4945
Unknown	177				177
Total	9937	100.0	7371	100.0	17308

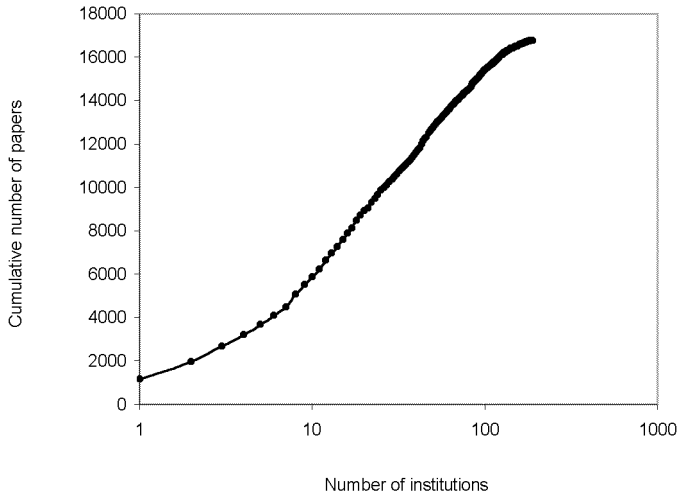

Figure 2. Cumulative number of papers vs. the number of institutions

Some institutions have more than one campus, each carrying out research that can be indexed in *Mathsci*. For example, TIFR has a centre in Bangalore and ISI has four centres in all. These have been listed individually in this table. However, Institute of Technology, Varanasi, has been merged with Banaras Hindu University.

Data in this table are presented for an initial five-year period and a later six-year period. On a per year basis, between the two periods, the number of papers has increased by about 12% for all India. Some of the leading institutions have also recorded substantial increases: TIFR, Mumbai, 16.5%; ISI, Calcutta, 7.5%; University of Calcutta, 28%; IISc, Bangalore, 53.6%; and ISI, New Delhi, 79%. In contrast some institutes have recorded a decline in the number of papers: BHU, Varanasi, 35.6% and IIT, Kanpur, 15%.

Classification by institution type

Academic institutions - universities and colleges - have published more than 77% of papers, and research institutions of the central government have published 13% of the papers. General universities have published 11,490 papers and institutions under the Department of Atomic Energy have published 2,084 papers (Table 7). These include 1,261 papers from the Tata Institute of Fundamental Research, 361 papers from the Institute of Mathematical Sciences, Chennai, and 80 papers from Mehta Research Institute, Allahabad, all the three institutions especially strong in mathematics. Institutions under the central ministries have published 1,536 papers and these include 1,434 papers published by the Indian Statistical Institute (which is also an academic institute of national importance). A private institution, SPIC Science Foundation, Chennai, headed by C. S. Seshadri, FRS, and devoted to pure mathematics and theoretical computer science, has published 50 papers.

Geographic distribution

The 17,308 papers in our data set have come from 134 cities/ towns. The four metropolitan cities lead the field [Calcutta: 2,218 papers; Mumbai: 1,674 papers, New Delhi (including Delhi): 1,638 papers, and Chennai: 1,354 papers]. These are followed by Bangalore (911) and Varanasi (592). All other cities/towns have contributed less than 450 papers (Table 8). Only 17 cities (including the four metropolitan cities) have published more than 200 papers. At the other extreme, 17 towns have published three papers or less. The ranks of cities and towns did not remain the same throughout the 11 years.

Table 7
Contributions made by different organization types as seen from *Mathsci* 1988-1998

Organization type	1993-98	1988-92	Total
Academic (excluding ISI)	7378	5908	13286
Research (Apex agencies)	1374	872	2246
Ministry (Central Government)	947	589	1536
Private Foundation	50	–	50
State Government	11	2	3
	9760	7371	17131
Academic			
Universities			
General	6592	4898	11490
Agricultural	70	96	166
	6662	4994	11656
Colleges			
General	555	614	1169
Engineering	160	278	438
Agricultural	1	22	23
	716	914	1630
Research Institutions			
Dept of Atomic Energy	1277	807	2084
ICAR	33	57	90
CSIR	24	6	30
Dept of Space	40	–	40
DRDO	–	2	2
	1374	872	2246
Central Ministries			
Planning (including ISI)	904	530	1434
Science and Technology	38	52	90
Human Resources Development	5	5	10
Defence	–	2	2
	947	589	1536
Private Foundations	50	–	50
State Govt Institutions	11	2	13
Total			17131

Table 8
Indian cities contributing in the field of mathematics as seen from *Mathsci* 1988-98

No.	City	State	1993-98		1988-92		Total
			No. of papers	%	No. of papers	%	
1	Calcutta	West Bengal	1269	12.77	949	12.9	2218
2	Mumbai	Maharashtra	958	9.64	716	9.7	1674
3	New Delhi	Delhi	963	9.69	675	9.1	1638
4	Chennai	Tamil Nadu	895	9.01	459	6.2	1354
5	Bangalore	Karnataka	593	5.97	318	4.3	911
6	Varanasi	Uttar Pradesh	261	2.63	331	4.5	592
7	Kanpur	Uttar Pradesh	217	2.18	226	3	443
8	Kharagpur	West Bengal	266	2.68	139	1.9	405
9	Aligarh	Uttar Pradesh	197	1.98	151	2	348
10	Bhubaneshwar	Orissa	195	1.96	102	1.4	297
11	Lucknow	Uttar Pradesh	170	1.71	110	1.5	280
12	Chandigarh	Chandigarh	163	1.64	108	1.5	271
13	Kalyani	West Bengal	165	1.66	96	1.3	261
14	Pune	Maharashtra	153	1.54	90	1.2	243
15	Aurangabad	Maharashtra	111	1.12	127	1.7	238
16	Jaipur	Rajasthan	83	0.84	139	1.9	222
17	Allahabad	Uttar Pradesh	138	1.39	65	0.9	203
18	Gorakhpur	Uttar Pradesh	55	0.55	143	1.9	198
19	Hyderabad	Andhra Pradesh	101	1.02	92	1.2	193
20	Sagar	Madhya Pradesh	130	1.31	61	0.8	191
21	Roorkee	Uttar Pradesh	100	1.01	77	1	177
22	Waltair	Andhra Pradesh	60	0.60	115	1.6	175
23	Jabalpur	Madhya Pradesh	95	0.96	73	1	168
24	Ahmedabad	Gujarat	57	0.57	94	1.3	151
25	Cochin	Kerala	90	0.91	60	0.8	150
26	Burdwan	West Bengal	89	0.90	49	0.7	138
27	Dharwad	Karnataka	66	0.66	71	1	137
28	Mysore	Karnataka	85	0.86	49	0.7	134
29	Ujjain	Madhya Pradesh	80	0.81	51	0.7	131
30	Jammu	Jammu & Kashmir	95	0.96	35	0.5	130
31	Ranchi	Bihar	53	0.53	75	1	128
32	Vallabh Vidyanagar	Gujarat	76	0.76	41	0.6	117
33	Bhilainagar	Madhya Pradesh	83	0.84	32	0.4	115
34	Guwahati	Assam	66	0.66	45	0.6	111
35	Jodhpur	Rajasthan	63	0.63	45	0.6	108
	99 other cities		1519	17.05	1362	18.60	3058
	Total		9760	100.00	7371	100.0	17308

For example, Chennai (formerly known as Madras) was fourth in 1990 (78 papers), third in 1994 (126 papers) and second in 1998 (107 papers). New Delhi was third in 1990 (116 papers), second in 1994 (135 papers) and fourth in 1998 (86 papers). Among states, only West Bengal has published more than 3,000 papers in the 11 years. Uttar Pradesh and Maharashtra have published more than 2,000 papers, and Tamil Nadu, Delhi and Karnataka have published more than 1,000 papers. All other states, barring Madhya Pradesh (917 papers), have published less than 500 papers. The Union Territory of Chandigarh has published 271 papers, largely thanks to Panjab University (268 papers), which has a strong mathematics department. While West Bengal has published the largest number of papers throughout the period, other states have changed their ranks. For example, Tamil Nadu, which held the fourth rank in 1994 (155 papers) and fifth in 1990 (99 papers), moved to the second position in 1998 (139 papers). Uttar Pradesh, which held the second position in 1990 (197 papers) and in 1994 (237 papers), has secured only the fourth position in 1998 (106 papers). Delhi held the fourth position in 1990 (116 papers), fifth in 1994 (135 papers) and sixth in 1998 (89 papers).

Use of journals of different impact factors

Table 9 gives the distribution of papers from selected institutions into impact factor ranges of journals. Extreme caution is necessary in interpreting the data presented in this table. Different subfields have journals of different impact factor ranges. Even important institutions like TIFR, ISI, and University of Calcutta publish a large number of papers in journals not indexed in SCI and other low-impact journals. May be SCI does not index some important mathematics journals. Looking at columns H, I and K, one notes that institutions under DAE account for a very large proportion of Indian papers in high impact journals. As pointed out earlier all these high impact journal papers are published in physics journals. For example, there are five papers in *Physics Reports* (impact factor 9.099), and these have come from TIFR, Institute of Physics, University of Madras (now the author of this paper and his group have gone to the Bharatidasan University, when part of the parent university was made into a new university), Banaras Hindu University and Saha Institute of Nuclear Physics.

Table 9
India's contribution to journal literature of mathematics categorised by leading institutions and impact factors of journals [*Mathsci* 1993-1998]

IF range→ Institutions	A	B	C	D	E	F	G	H	I	K	Total
Tata Institute of Fundamental Research, Mumbai	295	157	60	51	23	7	12	70	2	1	678
Indian Statistical Institute, Calcutta	254	126	25	37	11	1	0	5	0	0	459
University of Calcutta, Calcutta	350	55	1	19	2	0	0	0	0	0	427
Indian Institute of Science, Bangalore	161	95	37	31	9	1	1	5	1	0	341
Indian Statistical Institute Delhi	182	98	29	8	4	1	0	0	0	0	322
Indian Institute of Technology, Kharagpur	177	61	15	9	4	0	0	0	0	0	266
Indian Institute of Technology, Chennai	178	52	13	16	2	0	1	1	0	0	263
Banaras Hindu University, Varanasi	181	57	6	9	0	1	0	0	0	1	255
University of Delhi, Delhi	157	70	7	14	5	1	0	0	0	0	254
Institute of Mathematical Sciences, Chennai	91	38	8	60	14	0	9	11	4	0	235
Jadavpur University, Calcutta	82	39	25	48	6	4	3	0	1	0	208
Indian Institute of Technology, Kanpur	108	59	21	10	1	0	6	0	0	0	205
University of Madras, Chennai	140	52	1	7	2	0	1	0	0	1	204
Indian Institute of Technology, Mumbai	115	48	16	2	1	0	0	0	0	0	182
Aligarh Muslim University, Aligarh	161	19	1	0	0	0	0	0	0	0	181
Lucknow University, Lucknow	119	43	1	6	1	0	0	0	0	0	170
University of Kalyani, Kalyani	150	10	0	3	1	0	1	0	0	0	165
Panjab University, Chandigarh	88	59	8	6	1	0	0	0	0	0	162
Indian Institute of Technology, New Delhi	86	45	13	10	2	0	0	0	0	0	156
University of Poona, Pune	80	47	5	11	2	3	3	1	1	0	153
Dr. Hari Singh Gour University, Sagar	129	1	0	0	0	0	0	0	0	0	130
Indian Statistical Institute, Bangalore	78	36	5	0	0	0	0	0	0	0	119
Institute of Physics, Bhubaneswar	20	2	1	33	6	1	15	30	2	1	111
University of Roorkee, Roorkee	80	15	2	2	0	0	0	1	0	0	100
Marathwada University, Aurangabad	75	23	0	1	0	0	0	0	0	0	99
University of Jammu, Jammu	74	19	0	2	0	0	0	0	0	0	95
Cochin University of Science and Technology	52	30	1	6	0	0	0	1	0	0	90
Burdwan University, Burdwan	70	17	0	2	0	0	0	0	0	0	89
Kalyan Mahavidhyalaya, Bhillainagar	77	6	0	0	0	0	0	0	0	0	83
Utkal University, Bhubaneswar	63	11	2	4	0	0	2	0	0	0	82
Total	3873	1390	303	407	97	20	54	125	11	4	6284

A > 0.0
B > 0.0 - ≤ 0.5
C > 0.5 - ≤ 1.0
D >1.0 - ≤ 1.5
E >1.5 - ≤ 2.0
F >2.0 - ≤ 2.5
G >3.0 - ≤ 3.5
H >3.5 - ≤ 4.0
I >6.0 - ≤ 7.0
K >8.0

There are 17 papers in *Physical Review Letters* (impact factor 6.140) and these have come from Institute of Mathematical Sciences (4 papers), Bhabha Atomic Research Centre, Mumbai (3 papers), TIFR, Mumbai and Institute of Physics, Bhubaneswar (2 papers each), and IISc, Bangalore, Jadavpur University, University of Poona, Raman Research Institute, SPIC Science Foundation, and Saha Institute of Nuclear Physics (one each). 28 of the 94 papers in *Physics Letters B* (impact factor 3.581) have come from TIFR, Mumbai, 21 from Institute of Physics, Bhubaneswar, 14 from Mehta Research Institute, Allahabad, and 10 from Saha Institute of Nuclear Physics, Calcutta, and six from Institute of Mathematical Sciences, Chennai - all institutions belonging to the Department of Atomic Energy. Of the 68 papers in *Nuclear Physics B* (impact factor 3.531) 42 have come from TIFR, Mumbai, eight from Institute of Physics, Bhubaneswar, and six each from Institute of Mathematical Sciences, Chennai, and Mehta Research Institute, Allahabad. Of the 69 papers in *Physical Review D* (impact factor 3.420) 15 are from Institute of Physics, Bhubaneswar, 12 from TIFR, Mumbai, nine from Institute of Mathematical Sciences, Chennai, six from IIT Kanpur, five from Saha Institute of Nuclear Physics, Calcutta, and four from Raman Research Institute, Bangalore. Among the mathematics journals *Annals of Mathematics* (impact factor 2.071) had carried six papers from India, all from TIFR, Mumbai, and Journal of Fluid Mechanics had carried five papers from India, all from Indian Institute of Science, Bangalore. Of the 10 papers in *Journal of the American Statistical Association* (impact factor 1.851), six have come from ISI, Calcutta, and two from ISI, New Delhi.

Spectral distribution of research

An important part of bibliometric analysis is the breakdown of an institution's output into research fields.[10] That would provide an idea of the research profile of the institution. Conversely, one can also analyse the contributions of different institutions to a nation's output in a research field. Papers from different institutions indexed in *Mathsci* 1993-1998 are classified into subfields in Table 10. TIFR, Mumbai, is particularly strong in number theory (136 papers), algebraic geometry (105 papers), quantum theory (151 papers), computer science (46 papers) and relativity and gravitation (47 papers). Institute of Mathematical Sciences, Chennai, is another institution strong in number theory (26 papers), quantum theory (84 papers) and computer science (33 papers). In contrast, Institute of Physics, Bhubaneswar, another DAE institution, has hardly published anything in most areas of mathematics, its strong areas being quantum theory (82 papers) and to some extent relativity and gravitation (14 papers).

Table 10
India's contribution to journal literature of mathematics categorised by selected institutions and subfields

Subfields \ Institutions →	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	Total
62 Statistics	0	203	74	2	80	2	0	27	37	0	0	39	12	18	6	45	7	37	2	78	0	745
81 Quant-Theory	151	61	20	20	24	6	11	0	22	84	17	12	5	2	0	0	1	7	4	3	0	539
54 General-topology	0	11	65	0	1	10	12	17	14	0	3	1	30	0	12	0	16	1	1	0	106	333
90 Econom-oper-res	2	6	11	30	48	51	16	28	35	0	4	10	3	17	2	0	6	2	36	0	0	329
68 Comput Sci	46	29	9	25	0	41	18	0	0	33	7	29	1	19	0	0	0	0	21	0	0	282
83 Relat-Gravitat	47	6	4	5	0	4	5	46	4	13	49	3	0	1	2	0	5	0	1	23	0	237
11 Number-theory	136	0	0	1	0	0	4	1	1	26	0	4	5	0	0	10	0	21	0	1	0	213
60 Probability-theory-and -stochastic-processes	8	37	2	15	49	9	15	1	16	0	0	3	7	2	0	0	0	3	11	14	0	210
47 Operator-theory	0	0	3	3	24	5	5	5	25	4	2	3	5	6	11	0	1	7	2	10	11	201
53 Differential-geometry	5	0	22	3	0	0	0	44	0	1	3	0	0	2	10	26	70	0	0	0	0	186
46 Functional-analysis	0	7	5	0	13	8	6	17	24	3	0	6	16	1	14	1	6	1	4	2	0	178
30 Functions-of-a-complex-variable	2	0	17	0	0	19	2	1	2	4	14	16	32	0	3	4	4	0	1	3	0	158
16 Associative-rings-and-algebras	4	0	26	0	0	5	38	5	7	0	1	0	3	4	27	1	0	10	3	2	7	152
05 Combinatorics	14	16	2	16	7	5	31	0	3	3	1	7	4	19	1	1	0	0	6	5	0	150
33 Special-functions	0	1	36	0	1	0	1	22	0	8	0	0	2	0	20	41	0	0	1	0	0	142
76 Fluid Mechanics	0	7	10	45	0	10	7	6	2	0	8	3	0	7	1	5	2	10	7	0	0	133
20 Group-theory-and-generalizations	9	0	29	0	0	9	29	0	16	1	0	0	3	2	6	1	0	8	3	0	0	126
93 System-theory	1	2	7	41	3	34	4	0	0	0	0	5	0	20	0	0	0	0	7	0	0	126
65 Numerical analysis	0	8	3	20	2	6	7	0	10	0	4	18	0	22	0	2	1	0	13	1	0	121
14 Algebraic-geometry	105	0	0	1	1	0	0	0	0	4	0	0	0	1	0	0	0	1	0	0	0	113
58 Global-analysis,-analysis-on-manifolds	9	3	3	9	1	0	1	1	6	6	39	0	2	2	0	0	0	0	0	2	0	91
35 Partial-differential-equations	5	1	0	35	3	0	1	1	0	4	9	1	2	3	0	0	0	8	1	1	0	79
Total	544	398	348	271	257	224	213	222	224	194	161	160	132	148	115	137	119	116	124	145	124	4376

A - Tata Inst of Fundamental Res, Mumbai
B – Indian Stat Inst, Calcutta
C – University of Calcutta, Calcutta
D – Indian Inst of Science, Bangalore
E – Indian Stat Inst, New Delhi
F – Indian Inst of Technol, Kharagpur
G – Indian Inst of Technol, Chennai
H – Banaras Hindu University, Varanasi
I – University of Delhi, New Delhi
J – Inst of Mathematical Sci, Chenna
K – Jadavpur University, Calcutta
L - Indian Inst of Technol, Kanpur
M – University of Madras, Chennai
N - Indian Inst of Technol, Mumbai
O – Aligarh Muslim University, Aligarh
P – Lucknow University, Lucknow
Q – University of Kalyani, Kalyani
R – Panjab University, Chandigarh
S – Indian Inst of Technol, New Delhi
T – University of Poona, Pune
U – Dr. Hari Singh Gour University, Sagar

(Source: *Mathsci* 1993-1998)

Mehta Research Institute of Mathematics and Mathematical Physics, Allahabad, has published 23 papers in quantum theory, 18 in number theory, six in relativity and gravitation, and four in topological groups, Lie groups. All high-impact journal papers of Mehta Institute are in physics journals: 14 papers in *Physics Letters B* and six in *Nuclear Physics B*. Panjab University, Chandigarh, is strong in number theory (21 papers), field theory and polynomials (25 papers out of a total of 33 papers from all Indian institutions), and statistics (37 papers). Indian Statistical Institute, Calcutta, is strong in statistics (203 out of 1,149 papers from India), quantum theory (61 papers), computer science (29 papers) and combinatorics (16 papers). Other institutions strong in statistics are ISI, New Delhi (80 papers), University of Poona (78), University of Calcutta (74 papers), Lucknow University (45 papers), and IIT, Kanpur (39 papers). Out of the 671 papers in general topology, 106 are from Dr Hari Singh Gaur University, Saugar, 65 from University of Calcutta, 30 from University of Madras, Chennai, 23 from Burdwan University and 17 from Banaras Hindu University. Other institutions strong in combinatorics are Indian Institute of Technology, Chennai (31 papers), Indian Institute of Technology, Mumbai (19 papers), Indian Institute of Science, Bangalore (16 papers) and TIFR, Mumbai (14 papers). There were 296 papers in probability theory and stochastic processes. Of these, 49 had come from Indian Statistical Institute, New Delhi, 37 from ISI, Calcutta, 16 from University of Delhi, 15 each from Indian Institute of Science, Bangalore, and Indian Institute of Technology, Chennai, and 14 from University of Poona, Pune. Of the 432 papers in the subfield 'Economics, operations research, programming, games', 51 papers are from IIT, Kharagpur, 48 are from ISI, New Delhi, 36 from IIT, New Delhi, 35 from University of Delhi, 30 from IISc, Bangalore, and 28 from Banaras Hindu University, Varanasi. Of the 220 papers in fluid mechanics, 45 are from IISc, Bangalore, and 10 each from Panjab University, University of Calcutta and IIT Kharagpur. Of the 163 papers in systems theory, 41 are from IISc, 34 from IIT Kharagpur and 20 from IIT Mumbai. Of the 322 papers in computer science, 46 are from TIFR, Mumbai, 41 from IIT Kharagpur, 33 from Institute of Mathematical Science, Chennai, 29 each from IIT Kanpur and ISI, Calcutta, and 25 from IISc, Bangalore. SPIC Science Foundation, Chennai, the only private foundation active in mathematics research in India, has concentrated on algebraic geometry (15 papers), computer science (10 papers) and functions of a complex variable (6 papers).

One notes that work in certain areas is dominated by one or two institutions and work in other areas is spread over a large number of institutions. For example Marathwada University in Aurangabad has published 44 of the 122 papers in real functions, ISI, New Delhi, has published 54 of the 106 papers in linear and multi-linear algebra, and TIFR, Mumbai, has published 79% of all Indian papers in algebraic

geometry, and about 42% of papers in both number theory and 'topological groups, Lie groups'. In quantum theory at least eight institutions have published 20 or more papers, and in statistics at least ten institutions have published 25 or more papers. In the same manner, some institutions are focused on a small number of areas (e.g., Dr. Hari Singh Gaur University on general topology), whereas others have expertise over a larger number of areas (e.g., University of Calcutta).

Often researchers are faced with the problem of choosing between national journals (almost all of them poorly circulated) and more prestigious foreign journals. While publishing in more visible foreign journals is certainly more attractive, it is necessary to build national journals as they would give greater opportunities to evaluate one another's work. Mathematicians of TIFR, Mumbai, and Indian Institute of Science, Bangalore, have published many papers in the *Proceedings of the Indian Academy of Sciences*, whereas those of University of Calcutta, Burdwan University and Kalyani University have published many papers in the *Bulletin of the Calcutta Mathematical Society*.

International collaboration

Among the major S&T databases *Mathsci* is the only database other than the citation index databases of ISI which provide the affiliations and addresses of all authors of multi-authored papers. Analysing the information given in the address field, one can get an idea of the extent of domestic and international cooperation. We have analysed such data for papers indexed in *Mathsci* in the six years 1993-1998.

Of the 9,760 papers from India, the authorship in 8,283 papers is entirely from India. In 1,378 papers, there is at least one author from one other country and in 99 papers there is at least one author from two other countries. That works out to 1,477 internationally coauthored papers or 15.1% all Indian papers indexed in *Mathsci* during the six years. This is comparable to the 14% internationally coauthored papers in all of science in 1991 as seen from SCI 1991[9] and 17.6% in 1998 as seen from SCI 1998.[12,13] Of these 1,477 papers, 1,207 are written by authors from two institutions – one Indian and one foreign; 76 are written by authors from two Indian institutions and one foreign institution, 191 are written by authors from one institution each from India and two other countries; two papers are written by authors from one Indian and three US institutions; and one paper is authored by researchers from one Indian institution, one Irish institution and two US institutions. In all there are 1,576 collaborative links.

Of the 8,283 entirely Indian papers 7,439 are from a single institution, 804 are written by researchers from two institutions, 39 are written by authors from three institutions and one paper is written by authors from four institutions.

USA is the most prominent collaborating nation; US authors figure in 541 papers. Canada is the second most prominent collaborator with Canadian authors figuring in 236 papers. Germany (103 papers), France (70 papers), Italy (64 papers), Japan (60 papers), the UK (58 papers), and the Netherlands (38 papers) have also collaborated with Indian mathematicians to a notable extent in these six years.

Discussion

Varadarajan,[1] Narasimhan[2] and Seshadri[3] have attributed much of what has been achieved in mathematics research in Independent India to mainly Tata Institute of Fundamental Research and Indian Statistical Institute. They have also brought out the importance of individuals – both teachers and leaders in higher education. For example, Chandrasekharan's contribution in building the school of mathematics at TIFR is well known. The role played by Asutosh Mookerjee as vice-chancellor at Calcutta, and by S. Radhakrishnan and C. R. Reddy as successive vice-chancellors of Andhra University in attracting and retaining excellent mathematicians has been highlighted by Narasimhan.[2] He has also attributed the lack of development of truly vibrant schools at Madras till about the 1990s to poor leadership. In particular, he attributes the failure of Madras University to have developed a superior mathematics department to the prejudices of a long-time vice-chancellor. Andre Weil[11] attributes a similar negative influence in Calcutta to a professor, who headed the Mathematics Department at Calcutta during the reign of Asutosh Mookerjee and wielded considerable influence all over Northern India.

All the three chroniclers[1–3] also lament the sad state of training and research in Indian universities. With a few exceptions, such as Ganapathi Iyer of Annamalai University, R. P. Bhambha of Panjab University, Hans Raj Gupta and Shrikhande, university teachers have not made a mark in research.[3] None of the universities have come up to the international levels, says Seshadri.[3] "We have failed in having institutions where high level research and teaching go together." Echoes Varadarajan:[1] "... the basic mathematics curriculum has not been changed except perhaps in a cosmetic fashion and that there is a virtual famine of well-motivated and qualified teachers." In his opinion, the efforts to develop the advanced institutions (TIFR and ISI) were not accompanied by a comparable effort to revitalize the instructional programme in the universities. Says Narasimhan:[2] "The colleges in India have, however, not improved very much. ... the quality of the teachers in these colleges has not improved substantially...". Andre Weil felt the same way too: "Unfortunately the progress in the universities has been far less than what one had hoped" (quoted from Seshadri[3]). I am afraid, the situation has not changed even in the new millennium.

Thanks to the poor training at the Masters level, the leading schools of mathematics research find it difficult to get high quality doctoral students. In fact, the major centres like TIFR, ISI and IMSc provide several courses to students before they start their doctoral thesis work. Another striking feature is that there are not many women mathematicians in India. One bright spot is that several Indian youngsters perform well in the Mathematics Olympiad. It is at the Bachelors and Masters levels mathematics education and curricula need sprucing up, and teaching and learning revitalised.

The future of mathematics, it appears, depends a great deal on the few DAE institutions, ISI and the Board of Higher Mathematics. Although more than three-fourths of publications emanate from the academic sector, there is a widespread feeling that the strength is merely in terms of numbers and not in quality. The University Grants Commission and the Academies should think of ways to improve the overall standards of teaching mathematics at the college and university levels.

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