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National Mapping of Science

A bibliometric assessment of India's Scientific Publications based on Science Citation Index (1990 & 1994)

Aparna Basu and P.S. Nagpaul

National Institute of Science Technology, and Development Studies
Dr. K.S. Krishnan Marg, New Delhi 110 012, INDIA

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With compliments from;

For Copies Contact: Dr. Aparna Basu
National Institute of Science, Technology & Development Studies
Dr. K.S. Krishnan Marg, Pusa Campus, New Delhi-12.
Phone: 5726406, 5729151, 577-3178 (Direct)
Fax: 011-5754640
e-mail: aparna@csnistads.ren.nic.in

Preface

In a country of the size of India with a large scientific establishment, it becomes imperative to have up-to-date statistics on inputs into the scientific system, such as funds or manpower, as well as output in the form of publications, patents and projects. While information on inputs is regularly disseminated by the *Department of Science and Technology* through their reports, detailed output statistics are not so readily available. One reason for this gap is the dispersed nature of the information which makes any comprehensive compilation a difficult task. On the other hand, commercial databases of abstracting and citation services provide us access to the bibliographic details of the papers from any country published in the journals covered by the abstracting service, without the need to compile them from output details of numerous institutions all over the country. The present study is exploratory in nature using bibliometric techniques to analyse data from only two editions (1990 and 1994) of the *Science Citation Index*. The activity should be repeated at regular intervals of one or two years in order to provide a factual account of India's scientific activity on a continuing basis.

The double role of research publications both as an output of certain activities (i.e. reporting of research results) and as an input to another set of activities (which cite the study used) make it a useful indicator of scientific research. Without going into questions of how, or if at all, two published units are comparable, we simply say that the number of publications provides a 'count' or quantitative measure of output that can have a certain aggregate *impact* on the research system and may therefore be considered as a primary indicator of research activity. The count of citations acts as a measure of the *usefulness* of a research in the subsequent stages of the collective process of scientific knowledge generation, and provides a second indicator that is independent of the first.

There have been extended and continuing debates on the utility of simple counts as a measure of scientific activity, whether these counts can reflect the quality of science, its relevance, or, indeed, if it can replace peer evaluation. While these issues are still under discussion, it may perhaps be emphasized here that bibliometric methods are valid only in a statistical sense and may be suitable for large groups or institutions and nations rather than individuals. For the latter, peer assessment must be used alongside other indicators. Quality of research is often difficult to ascertain except by hindsight. Yet it is important for funding agencies and policy makers to assess the output of specific programs or institutions. The routine generation of bibliometric indicators gives a ready means of comparative evaluation of national output vis-a-vis other nations, or of states, sectors or institutions.

Keeping the above mentioned requirements in mind, the study titled *National Mapping of Science* was begun as a national level exercise to be executed by several groups from all over the country. The study was initiated and sponsored by the *National Information System for Science and Technology* (NISSAT), *Department of Scientific & Industrial Research* (research grant No. JSF/1496/96).

The objective was to analyse Indian scientific publications appearing in a number of commercial bibliographic databases. The database to be analysed at the *National Institute of Science Technology and Development Studies* (NISTADS) was the *Science Citation Index* (SCI). The parameters of the study included,

1. Output in different scientific fields & subfields
2. Journals used and Impact Factor of publications
3. Output at the state, sectoral and institutional levels
4. Collaboration patterns

Citations have not been considered.

This study could not have been completed without the dedicated efforts of the team members; Shri P.S. Nagpaul (*Project Investigator*) who provided the intellectual support and journal classification scheme and Chapters 10 & 11 of the study report, and who was the source of a steady stream of ideas and suggestions based on his extensive knowledge of current literature, Shri K.C. Garg who provided the country of publication of journals from Ulrich Directory, Smt. Ritu Aggrawal who undertook the major task of creation of database, programming and graphics, Shri Narendra Kumar who undertook the word processing, data classification and input, Shri B.S. Vinu Kumar, who painstakingly cross-checked data, and helped with tables, graphics and report preparation. It is my pleasure to acknowledge their contribution. Every member of the Business Promotion Group at NISTADS has helped on a day to day basis - Drs. P.V.S. Kumar and Radha Chakravarty, Shri S.A. Nabi and Shri P.K. Nair. NISTADS staff have provided assistance on every occasion. I would like to thank each one of them and all colleagues who have provided friendly advice and support.

We are deeply indebted to NISTADS director Dr. Ashok Jain, for guidance, encouragement and support throughout the study period and for infrastructural facilitites.

We also express our gratitude to NISSAT Advisor Dr. A. Lahiri for his generous help and advice and Smt. Sreedevi Ravindran and Smt. Kamini Mishra of NISSAT for their help in matters related to administrative details of the project.

Aparna Basu
(on behalf of research team)

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RESEARCH TEAM

1. Ashok Jain

   Ph.D (Physics), Director, National Institute of Science, Technology & Development Studies(NISTADS).

2. P.S. Nagpaul (Project Investigator)

   M.Sc (Statistics), Retd. Scientist, National Institute of Science, Technology & Development Studies(NISTADS).

3. Aparna Basu (Co-investigator)

   Ph.D (Physics), Scientist, National Institute of Science, Technology & Development Studies(NISTADS).

4. K.C. Garg

   M.Sc(Math), Scientist, National Institute of Science, Technology & Development Studies(NISTADS).

5. Ritu Aggarwal

   B.A(English), Project Assistant, Diploma in Computer Applications.

6. B.S. Vinu Kumar

   M.Sc(Tech), Project Assistant.

7. Narendra Kumar

   Project Assistant.

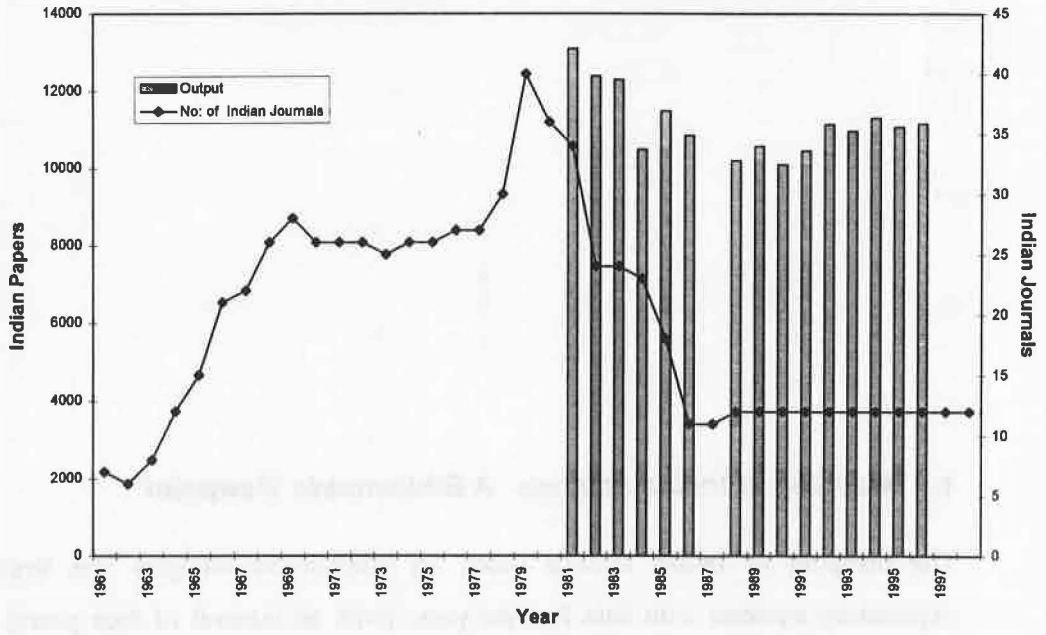
1 Executive Summary

1.1 Mapping of Indian Science: A Bibliometric Viewpoint

The mapping of Indian science based on bibliometric analysis was begun as an exploratory exercise with data for two years (with an interval of four years) from the Science Citation Index [1]. The objective was to extract information on India's scientific activity through an analysis of its publications from information readily available in the public domain, and to critically assess if this tool gave a meaningful picture of India's scientific activity. Another objective was to build up a database of Indian publications from which long and short term changes could be analysed. It needs to be emphasized at the outset that bibliometric techniques are statistical and their validity relies upon using a large volume of data extending over a sufficient period of time. Too much stress should therefore not be put on actual numbers or counts, but on eliciting underlying patterns . This is especially true when the numbers are small.

Choice of database: The Science Citation Index (*SCI*) is brought out annually on CD-ROM by the Institute for Scientific Information, USA *(ISI)*. Although it covers as many as 4000 journals in all fields of science, nevertheless it can only give a partial account of the publications for any country including India, due to lack of comprehensive coverage of journals. This point must be kept in mind while discussing India's output of scientific papers based on SCI data. Over the last decade, Indian journals included in the *SCI* have declined from a high of 40 journals to the present value of 12 journals. The coverage of Indian journals and papers in both domestic and international journals in the SCI over the years is shown in Figure 1.1.1.

Fig 1.1.1 Papers from India & Indian Journals indexed in the SCI



Other subject specific data-bases may offer a larger coverage of Indian scientific output , but seamless merging of data bases is not without its problems. Journals are included by *ISI* on the basis of certain selection criteria and standards. Coverage is less for countries publishing in languages other than English. While India does not have a problem in this respect, it does publish a large number of scientific periodicals that are not included in SCI. The adequacy of coverage of Third World science in SCI has been a subject of debate[2]. In spite of these problems, several countries have based their national performance evaluation on the Science Citation Index (Mexico, Australia, UK, Hungary). The *SCI* also lists the addresses of all authors of a paper and thus provides valuable information on international and domestic linkages. It is the only database that gives information on citations, which provides an independent dimension of the extent of utilization of research.

1.2 Data Processing, Enhancement and Methodology

The publications from the *SCI* database were selected as being Indian on the basis of the geographical location in India of any of the authors. In this study, more than 20,000 records of publications with journals, titles, multiple authors and addresses (comprising the Indian output for the years 1990 and 1994 indexed in the SCI,) were converted into a useable database. This was followed by classification of journals into disciplinary areas based on a methodology developed by Computer Horizons, Inc. (CHI). Journal *Impact Factors*[1] for 1994 and country of publication were introduced manually from the 1994 edition of the *Journal Citation Report* (JCR) [3] and *Ulrich Directory* [4]. The data in the address field were cleaned to remove multiple versions of the same address, and reduce addresses to a standard form. States and cities were extracted or introduced wherever missing. The addresses were coded to conform to the Directory on R&D Institutions [5] published by the Department of Science and Technology (DST).

1.2.1 Parameters of analysis

The parameters based on which we draw our conclusions regarding the state of Indian science as seen through its publications, are the following:

1. Number of scientific publications in different disciplines.
2. Change over the period 1990 to 1994
3. Impact factor and country of the Journals carrying Indian papers.
4. Output of different sectors in the major disciplines
5. Output of states in the major disciplines
6. Output of the major institutions
7. Collaboration patterns, both foreign and domestic
8. Structural Analysis

Information on titles, authors and references, also included in the database, were not utilised in this study.

A note on multiple counts: In collaborative papers, more than one individual, institution, state, sector or country may be associated with a single paper. Each one of them is assigned a full count for the paper while totalling the respective contribution to the publication output. This procedure does not undervalue collaborative work. However the total of the sectoral, state or institutional output will exceed the national output.

[1] A measure of journal use, defined in Chapter 3, as the ratio of citations received in a given year to the number of publications in the previous two years.

1.2.2 Performance Indicators

In order to obtain effective comparisons between units, such as states, which vary considerably in size and volume of output, we have used bibliometric indicators, viz. *Average Impact Factor*, *State level Activity Index* and *Visibility Index* [2](defined below,) apart from measures such as the *Network Centrality Index*

Impact factor of a journal is defined as the ratio of

number of citations to a journal in a given year / number of publications in the previous two years.

Average Impact Factor is defined as

Total Impact factor of all papers / Total number of papers

Activity Index of a state is defined as

Fraction of papers in a given discipline by state/ Fraction of papers in the same discipline in the country.

Visibility Index of ***X***(state/institution/sector) in a given discipline ***Y*** is defined as

Fraction of cumulative impact of *X* in a given discipline *Y*/ Fraction of Cumulative impact in the discipline *Y* in all *X*

Other details of methodology are given in Chapter 3.

International comparisons have not been made as that would require inputs from the total world data. Direct comparisons with the work of Braun et.al [6] on international output may also not be accurate due to differences in the classification scheme.

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[2] *A note on Impact Factor:* In this study we have only used the journal Impact Factors for 1994. Thus, the calculations of impact for the other year 1990 merely reflect the proportional change of papers in journals of a given IF in 1994, without being altered by the actual citation levels of the journals in 1990. In a sense this procedure separates out the change in IF that would arise from changes in journal standing, from those changes that are due to, say, a decline in the number of papers published in prestigious journals.

1.2.3 Type of Document

The ***SCI*** categorizes documents (papers) in terms of their ***type.*** The proportion of Indian publications in the different categories is indicated below

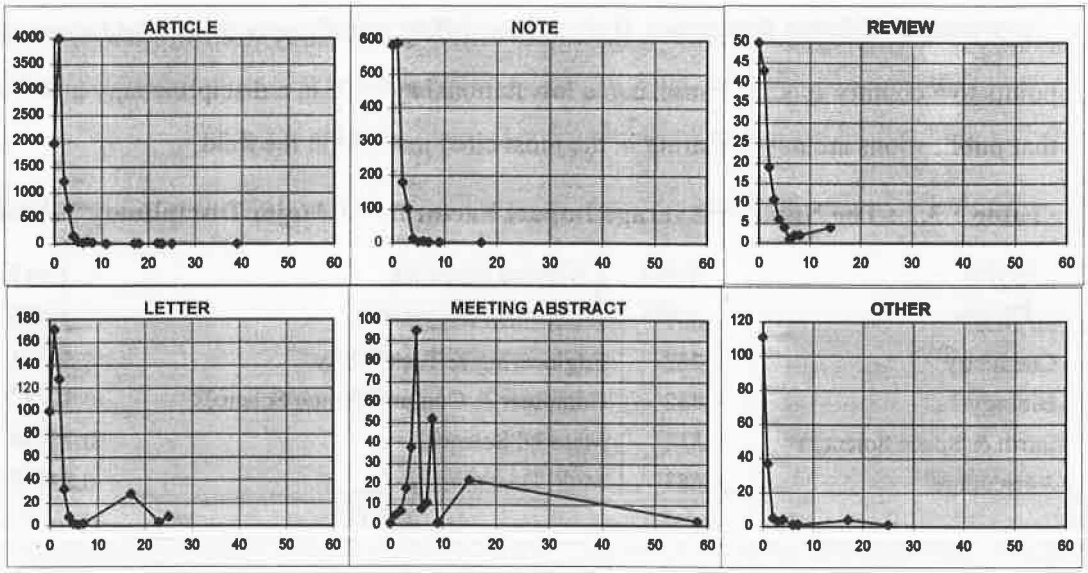
Table1.2.1 Percentage of Papers in Categories by Type

TYPE	1990	1994	*TYPE*	1990	1994
Article	78.9	77.0	Review	1.1	1.4
Note	13.2	13.4	Editorial	0.7	0.9
Letter	4.5	4.3	Discussion	0.2	0.3
Meeting Abstract	1.5	2.3	Biographical Item		0.2

We have included papers in all categories in this study. The proportion of papers by type for all the different disciplines is tabulated in Part II (Table 5, pg. AV.1).

The Impact Factor of documents of different types show interesting variations. For example the IF of journals that publish meeting abstracts have higher impacts. The distribution of Impact Factor by type of document is shown below in Fig. 1.2.1

Fig 1.2.1 Distribution of Impact Factor by Document Type



1.3 Major Disciplines in the Sciences[3]

Our data on India's publication output in the main disciplinary areas, viz Mathematics, Physics, Chemistry, Biology, Earth & Space Sciences, Agriculture, Clinical Medicine, Biomedical Research, Engineering & Technology, Computers & Communication , Materials Science and Multidisciplinary, shows that there has been growth in every discipline except Agriculture, which has declined. Other features are indicated below:

Table 1.3.1 : Main Characteristics of Publications in the Major disciplines

Highest Output '94	***Highest growth '90 -'94***
Chemistry, *Physics,* *Clinical Medicine*	*Biomedical Research* *Physics* *Engineering*
Highest Average Impact Factor '94	***Decline '90 - 94***
Medicine *Physics* *Biomedical Research*	*Agriculture*

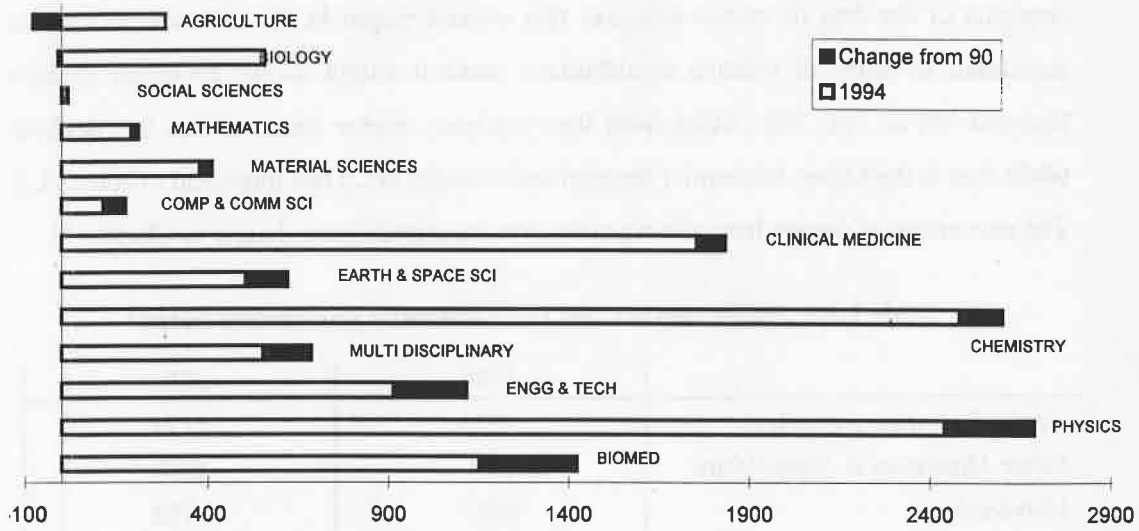
Table 1.3.2 indicates considerable variation in the national averages of the IF of different disciplines. This could be due to intrinsic reasons such as variations in the citation practices of different disciplines. If the values differs significantly from world averages it points to a country specific cause, e.g. a low national average in a discipline may indicate that publications are not appearing in the most cited journals in the field.

Table 1.3.2 : The National Average Impact Factor in the Major Disciplinary Fields

Maths	0.523	Clinical Medicine	1.917
Physics	1.607	Biomedical Research	1.576
Chemistry	1.262	Engineering & Technology	0.591
Biology	1.432	Computer & Communication Sciences	0.797
Earth & Space Sciences	0.812	Material Sciences	0.786
Agriculture	0.683	Multi Disciplinary	0.814
	Total	1.333	

[3] For details of sub-disciplines please see Chapter 5. For disciplinary profiles see section 5.4.

Fig 1.3.1 Papers in Major Diciplines in 1994 & Change from 1990



Changes in the output of papers in major disciplines are indicated in Fig. 1.3.1. The highest output of papers was in Chemistry, Physics, and Clinical Medicine, while the largest increase was in Biomedical Research and Physics. Papers on Agriculture showed a decline in this period.

1.3.1 Sub-disciplinary fields

The growth or decline in the sub-disciplinary fields within each major discipline are shown in Figure 5.2. The areas of marked change are shown in Table 1.3.3

Table 1.3.3 Output and Change in Sub-disciplinary areas in the Major Disciplines

Highest Output '94	***Highest growth '90 -'94***
General Physics (560) *Biochemistry and Molecular Biology (417)* *Physical Chemistry (372)* *Botany Plant science (332)* *General Materials Science (301)*	*Interdisciplinary Computer Applications (700%)* *Characterization of materials (700%)* *Embryology (400%); Virology (325%)* *Nephrology (325%); Urology (233%)* *Neurology & Neurosurgery (182%)* *Haematology (178%); Addiction (167%);* *Opthalmology (132%)* *Remote Sensing (217%)* *Aerospace Technology (141%)*
Highest Average Impact Factor '94	***Maximum decline '90 - 94***
General & Internal Medicine (22.673) General Biology (15.115) Cancer (9.455)	*Agricultural Economics and Policy (-75%)* *Psychology and Behavioural Science (-75%)* *Software & Graphics (-100%)*

1.4 Sectoral output of Scientific Publications and Impact

Analysis of the data by sector indicates that overall output in the different sectors has increased. In terms of relative contributions sectoral output shows no major changes between '90 & '94. The output from the Academic Sector (universities) has declined while that in the Other Academic(deemed universities, etc.) has increased (Table 1.4.1). The proportion of papers from the Agencies has increased (more details in Chapter 6).

Table 1.4.1 Major sectors and their scientific publication output

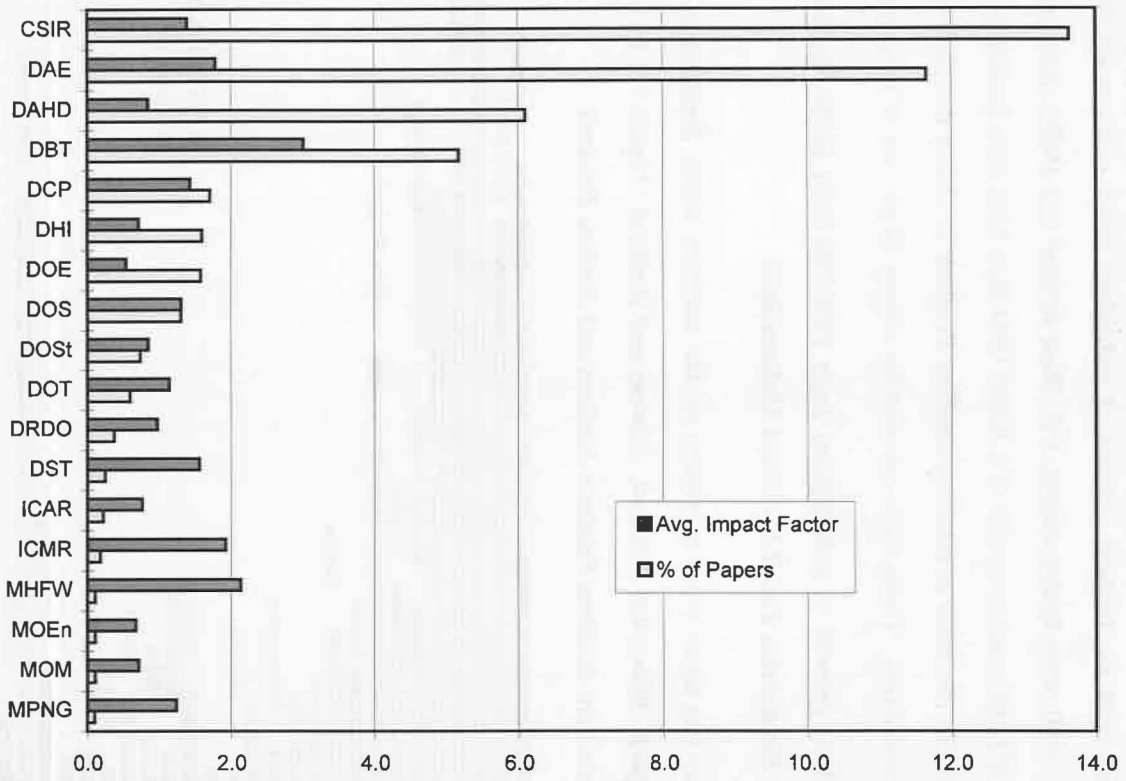
	1990	*1994*
Major Scientific Agencies,	*3831*	*5173*
Other Ministries & State Sector	*252*	*837*
Universities,	*4007*	*4188*
Others Academic Sector	*1979*	*2408*
Industrial Sector	*277*	*369*
Health Sector	*596*	*602*
Total	*11124*	*13267*

The volume of output and average *IF* of the Major Scientific Agencies are shown in Table 1.4.2). The high growth in the Department of Biotechnology (output doubled from '90 to '94) indicates that it is a burgeoning new area of activity. A high growth in Department of Electronics must be discounted due to the basic numbers being small. CSIR has the highest output, but has declined in relative terms.

Table 1.4.2 : Output of the Major Scientific Agencies

Agencies	***1990***	***% of output '90***	***1994***	***% of output '94***	***Av IF '94***
DAE	*918*	*8.25*	*1170*	*8.82*	*1.733*
CSIR	*1233*	*11.08*	*1451*	*10.94*	*1.325*
DRDO	*119*	*1.07*	*140*	*1.06*	*0.913*
DOE	*4*	*0.04*	*13*	*0.10*	*0.543*
MOEn	*20*	*0.18*	*30*	*0.23*	*0.562*
ICAR	*207*	*1.86*	*165*	*1.24*	*0.733*
ICMR	*149*	*1.34*	*170*	*1.28*	*1.649*
DBT	*23*	*0.21*	*59*	*0.44*	*2.929*
DST	*413*	*3.71*	*553*	*4.17*	*1.446*
DOS	*106*	*0.95*	*183*	*1.38*	*1.187*
MHFW	*460*	*4.14*	*493*	*3.72*	*2.034*

Fig 1.4.1 Percentage Output of Publications & Average Impact Factor per Paper
(Major Scientific Agencies: *SCI Data for India 1994*)



CSIR = Council of Scientific & Industrial Research
DAE = Dept. of Atomic Energy
DAHD = Dept. of Animal Husbandry & Dairying
DBT = Dept. of BioTechnology
DCP = Dept. of Chemicals & Petrochemicals
DHI = Dept. of Heavy Industry
DOE = Dept. of Electronics
DOS = Dept. of Space
DOSt = Dept. of Statistics
DOT = Dept. of Telecommunications
DRDO = Defence Research Development Organisation
DST = Dept. of Science & Technology
ICAR = Indian Council of Agricultural Research
ICMR = Indian Council of Medical Research
MHFW = Ministry of Health & Family Welfare
MOEn = Ministry of Enviroment & Forests
MOM = Ministry of Mines
MPNG = Ministry of Petroleum & Natural Gas

1.5 Scientific publications from Indian states

The *SCI* data showed that there were contributions from 26 states in 1990 and 28 states and Union Territories in 1994. As expected, there was a wide variation in the volume of output from different states and Union Territories, given their intrinsic differences in terms of size, institutions, financial outlay and scientific manpower. The concentration of scientific institutions around the metropolitan areas also accounts for the above differences and the present analysis must be refined to include this aspect. The output of the States and Union Territories are shown in Fig. 1.5.1.

The states with the **highest volume of published work** (with more than 1000 papers each) in 1990 were ***Maharashtra, UP, West Bengal*** and ***Delhi***, accounting for over 50 percent of India's output in the *SCI*. Since 1994 they have been joined by ***Karnataka*** and ***Tamil Nadu***, the latter overtaking ***Andhra Pradesh*** to obtain the sixth rank in terms of overall production. These states account for almost 70 percent of India's output.

The **highest growth** in publications since 1990 has been in the southern and western states of ***Karnataka, Tamil Nadu*** and ***Maharashtra.***

A **decline** has taken place in almost all the northern states, ***Rajasthan, Uttar Pradesh, Chandigarh, Himachal Pradesh, Jammu and Kashmir*** (Figure 1.5.1). Other states that have gained are ***Madhya Pradesh, Gujarat*** and ***Andhra Pradesh***.

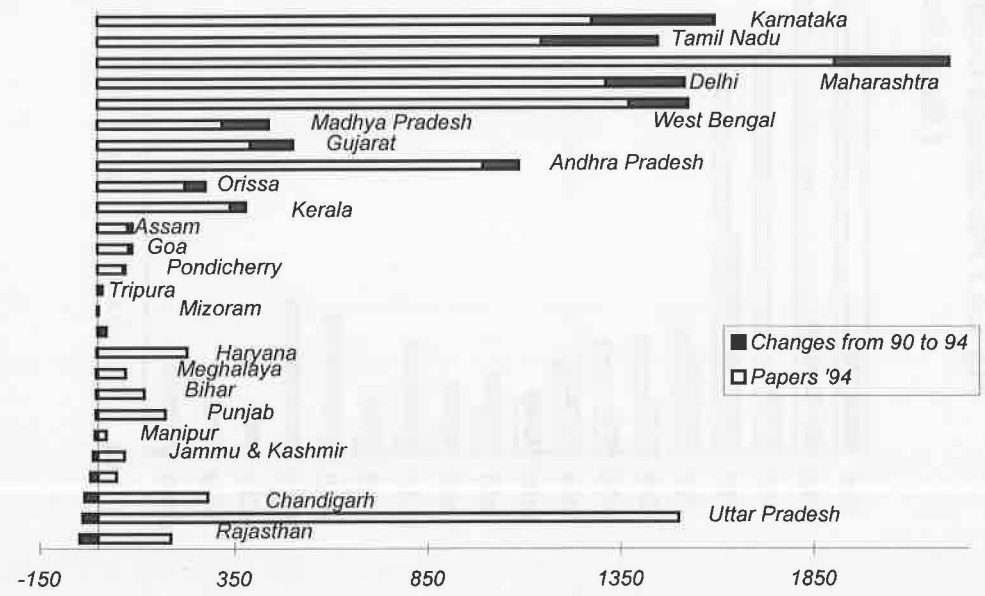


Fig 1.5.1 Output of Scientific Publications from Indian States SCI 1994

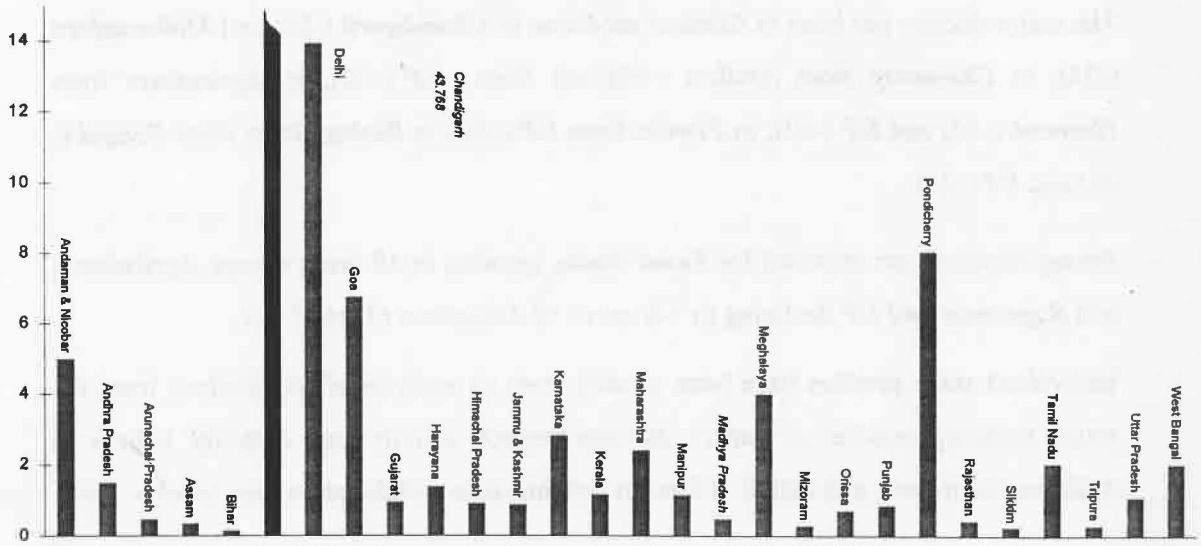
1.5.1 Scientific output of states per unit Population

When scaled for size differences by the population in each state, sharp differences emerge (Figure 1.5.2). This shows the extent of science orientation in the region. Not un-expectedly, the Union Territories, **Chandigarh, Delhi , Pondicherry** and **Goa** and **Andaman- Nicobar** had a higher output per lakh population. In 1994, **Chandigarh** was leading with an output of **43** papers per lakh population, followed by Delhi with **14** papers and Pondicherry with **8** papers respectively.

Among the larger states, **Karnataka** was leading with close to **3** papers, **Maharashtra** with **2.3** papers, and **Tamil Nadu** and **West Bengal** with **2** papers each.

Among the smaller states, **Meghalaya** outstripped the larger states with **4** papers per lakh persons.

Fig 1.5.2 Annual publication output of Indian states: per lakh population



1.5.2 Changes in State output in Major Disciplines

Analysis of our data shows that while national output has increased in every discipline (with the sole exception of ***Agriculture)***, at the state level there has been growth in certain disciplines and decline in others. The changes are shown in Fig. 7.1, a-c, and schematically in Table 1.5.1

The **maximum growth** has taken place in ***Physics*** (342 papers), followed by ***Biomedical Research*** (308) and ***Engineering*** (234). This is mainly accounted for by growth in certain states, (i.e.), ***Maharashtra*** for ***Physics***, ***Delhi*** for ***Biomedical Research***, and ***Karnataka*** for ***Engineering***.

The **highest net increase** has been in ***Physics*** from ***Maharashtra*** (109 papers); in ***Chemistry*** from ***Tamil Nadu*** (87)and ***Maharashtra*** (82); in ***Physics*** from ***West Bengal*** (70); in ***Biomedical Research*** in ***Delhi*** (63) and ***Karnataka*** (55); in ***Clinical medicine*** in ***Tamil Nadu*** (60); and in ***Engineering and Materials Science*** from ***Karnataka*** (49, 27) and ***Tamil Nadu*** (33, 16). Contributions to ***Multi disciplinary*** journals appears to have increased in ***Karnataka, Maharashtra*** and ***UP***. ***Computers***, a small field, appears to be growing in almost all the states, more significantly in ***West Bengal*** (18).

The major decline has been in ***Clinical medicine*** in ***Chandigarh*** (-52) and ***Maharashtra*** (-34), in ***Chemistry*** from ***Andhra*** (-45) and from ***UP*** (-32), in ***Agriculture*** from ***Haryana*** (-32) and ***UP*** (-32), in ***Physics*** from ***UP*** (-23), in ***Biology*** from ***West Bengal*** (-22) and ***UP*** (-21).

Strong contrasts are provided by ***Tamil Nadu***, growing in all areas except ***Agriculture,*** and ***Rajasthan and UP*** declining in 7-8 out of 12 disciplines (Table 7.1c)

Individual state profiles have been created from an analysis of publications from the states featuring number of papers, average impact, activity and visibility indices in different disciplines, and extent of foreign and interstate collaboration (see Section 5.4)

In Table 1.5.1 we show the position of the states above and below the state averages for output and Impact Factor.

Table 1.5.1a Classification of States based on Output & IF 1990

1990		Output: Above Average		Output: Below Average	
Impact Factor	Above Average	Maharashtra West Bengal Delhi Karnataka	I	Jammu & Kashmir Chandigarh	IV
	Below Average	Uttar Pradesh Tamil Nadu Andhra Pradesh	II	GUJ, KER, MAP, HAR, ORI, RAJ, PNJ, BIH, GOA, ASM, MEG, PON, MAN, TRI, ARN, MIZ, AND, SIK, HIM	III

Without going into the actual figures of the Productivity and Impact Factor it is seen that ***Maharashtra, Delhi,*** *and* ***Karnataka*** *have maintained an above average productivity and Impact Factor from 1990 to 1994.* ***West Bengal*** *has however, lost out in 1994 as its Impact Factor has gone below the national average in 1994.* ***Andhra Pradesh*** *on the other hand has crossed over the average line for IF.*

Among the states with smaller output(below National Average), ***Chandigarh*** *has maintained its IF above the National Average in both 1990 & 1994. The IFs of* ***Pondicherry, Arunachal Pradesh*** *and* ***Orissa*** *have gone past the national avergage since 1990.* ***J&K's*** *IF fell below the national average between 1990 & 1994.*

I - both Output and Impact Factor above the National Average.
II - Ouput above the National Average but Impact Factor below the National Average
III - below the National Averages in both Output and Impact Factor.
IV- below the National Average in their Outputs but above National Average in Impact Factor

Table 1.5.1b Classification of States based on Output & IF 1994

1994		Output: Above Average		Output: Below Average	
Impact Factor	Above Average	Maharashtra Delhi Karnataka Andhra Pradesh	I	Pondicherry Chandigarh Orissa Arunachal Pradesh	IV
	Below Average	Uttar Pradesh Tamil Nadu West Bengal	II	GUJ, KER, MAP, HAR, RAJ, PNJ, BIH, GOA, ASM, MEG, J&K, MAN, TRI, MIZ, HIM	III

1.6 Institutional Output and Impact

There were more than 17,000 addresses located in India in the SCI database for the years 1990 and 1994, of which 98.8 percent were institutional addresses and 0.2 percent were residential or private addresses. The institutional output was highly skewed, a few major institutions contributing a large percentage of the output. It may be said that the activities of these institutions constitute the core of Indian science.

As the unit of analysis gets smaller down to the institutional level, the question of data reliability and fluctuation becomes more acute. The interpretation of institutional productivity therefore needs to made with greater care. In this study no attempt has been made to adjust for differences in size between institutions.

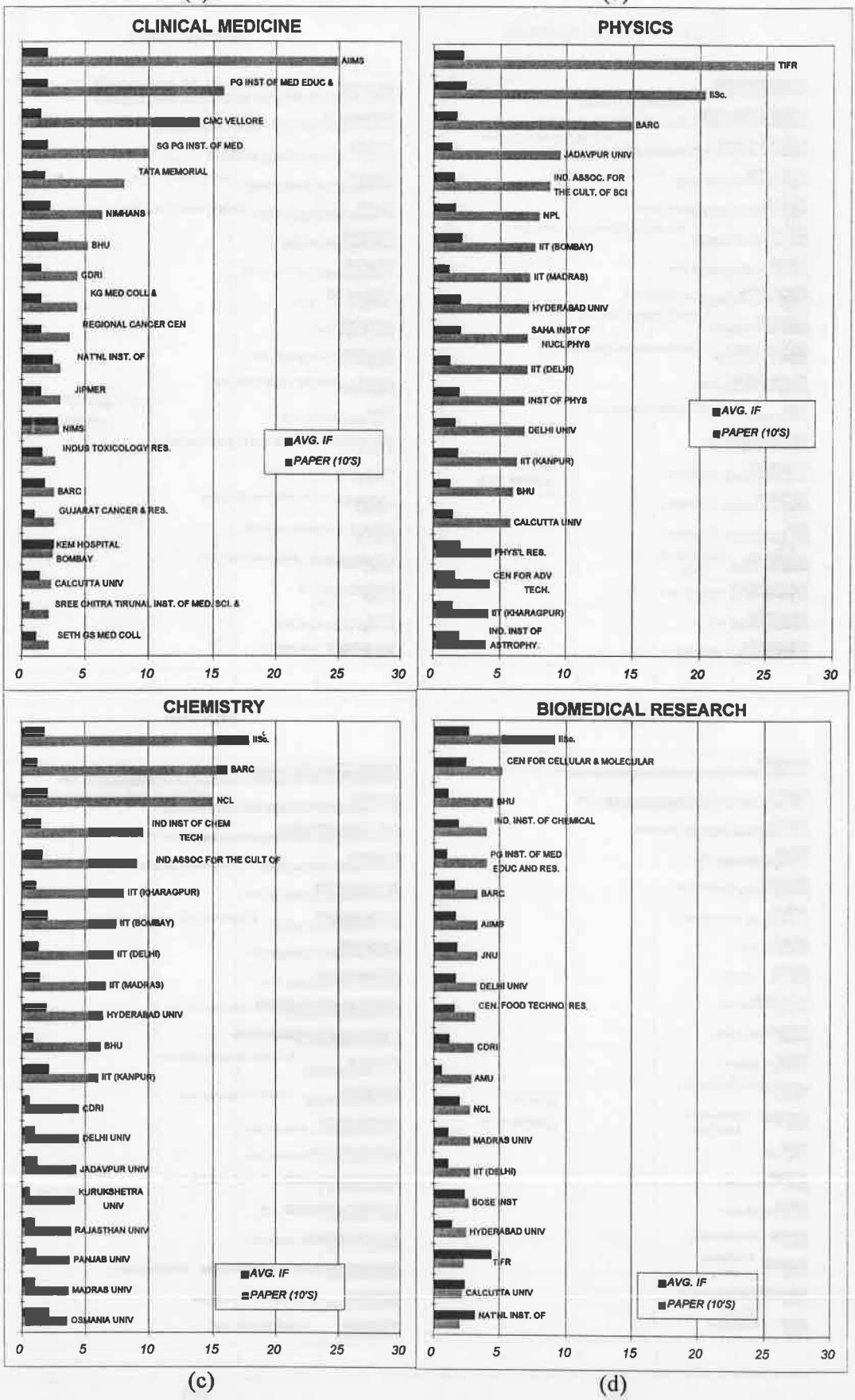
In order to damp out the effect of year-to-year fluctuations, we have based our calculations on the aggregated data for the years 1990 and 1994. The difference between the output in the 2 years indicates change. Whether this is the effect of fluctuation or an actual trend due to specific causal factors can only be determined by analyzing several years of data.

In Chapter 8, Fig 8.1(a-l) we have shown the institutions ordered by output in different disciplines, and their growth or decline (in terms of change in output in the 4 year interval). Only those institutions which were among the top 40 productive institutions in either of the years have been selected for display. We have also indicated the cumulative percentage of output in any discipline accounted for by these institutions.

The proportion of papers in different disciplines varies sharply between institutions. This is to be expected as institutions often specialize in a few or even a single discipline. Since the average IF for disciplines varies considerably, it is not meaningful to make a direct comparison of institutions using their average IF. Instead, comparisons may be made on the basis of the IF of papers contributed by the institutions within a single discipline A quick overview of institutional output and impact in 1994 are shown in Figures 1.6.1 (a-l).

Fig 1.6.1 SCIENTIFIC PUBLICATION OUTPUT OF INDIAN INSTITUTIONS - 1994

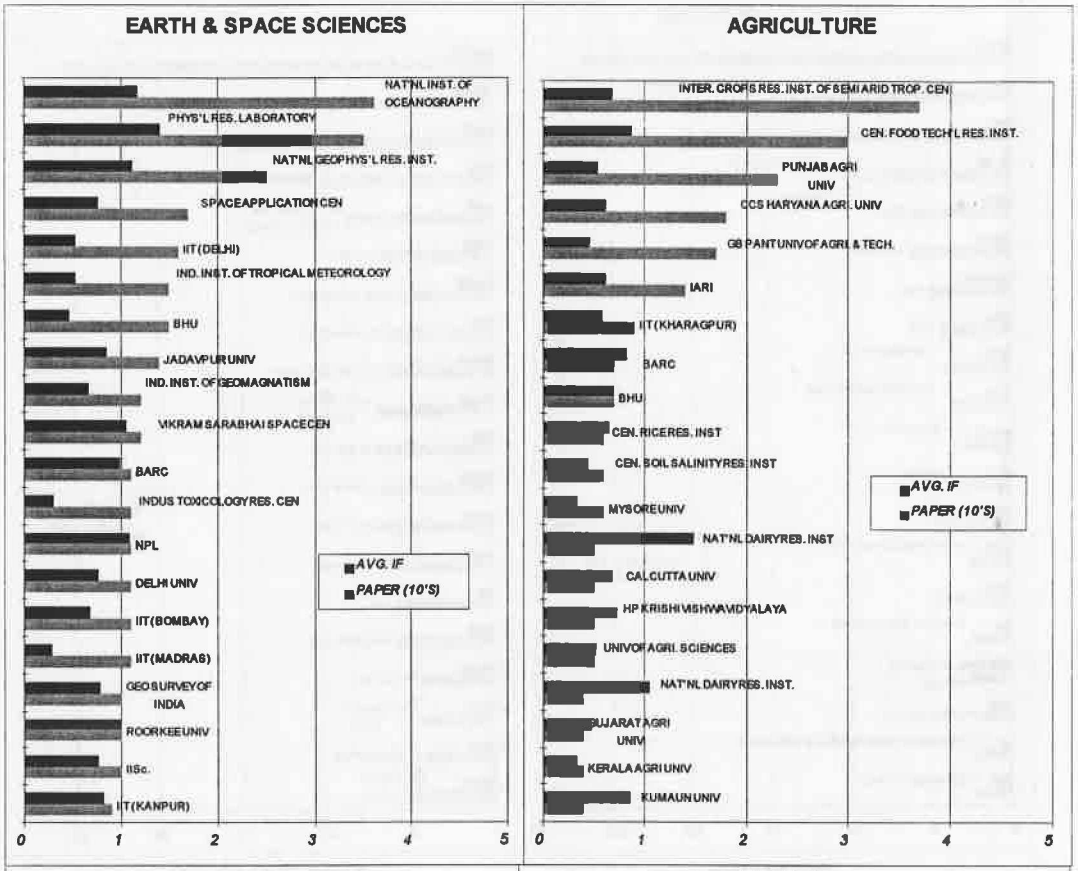
(a) (b)

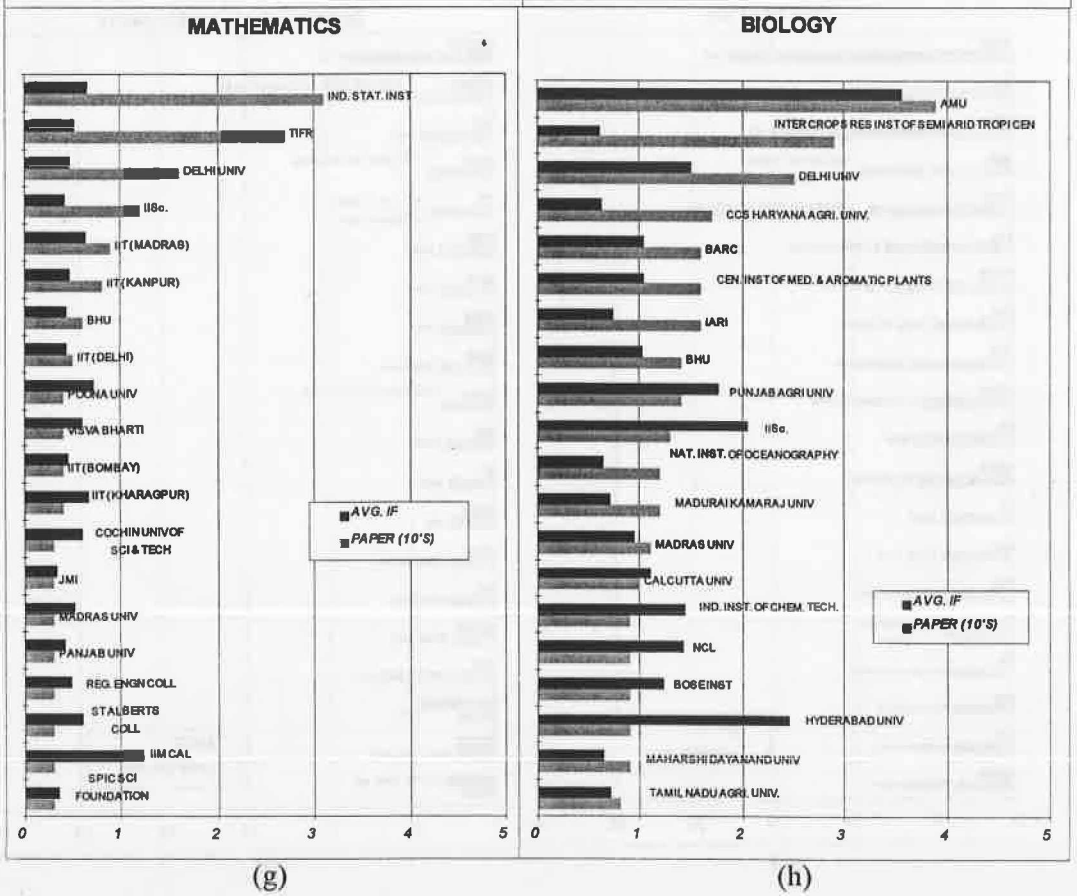


(c) (d)

Fig 1.6.1 SCIENTIFIC PUBLICATION OUTPUT OF INDIAN INSTITUTIONS - 1994

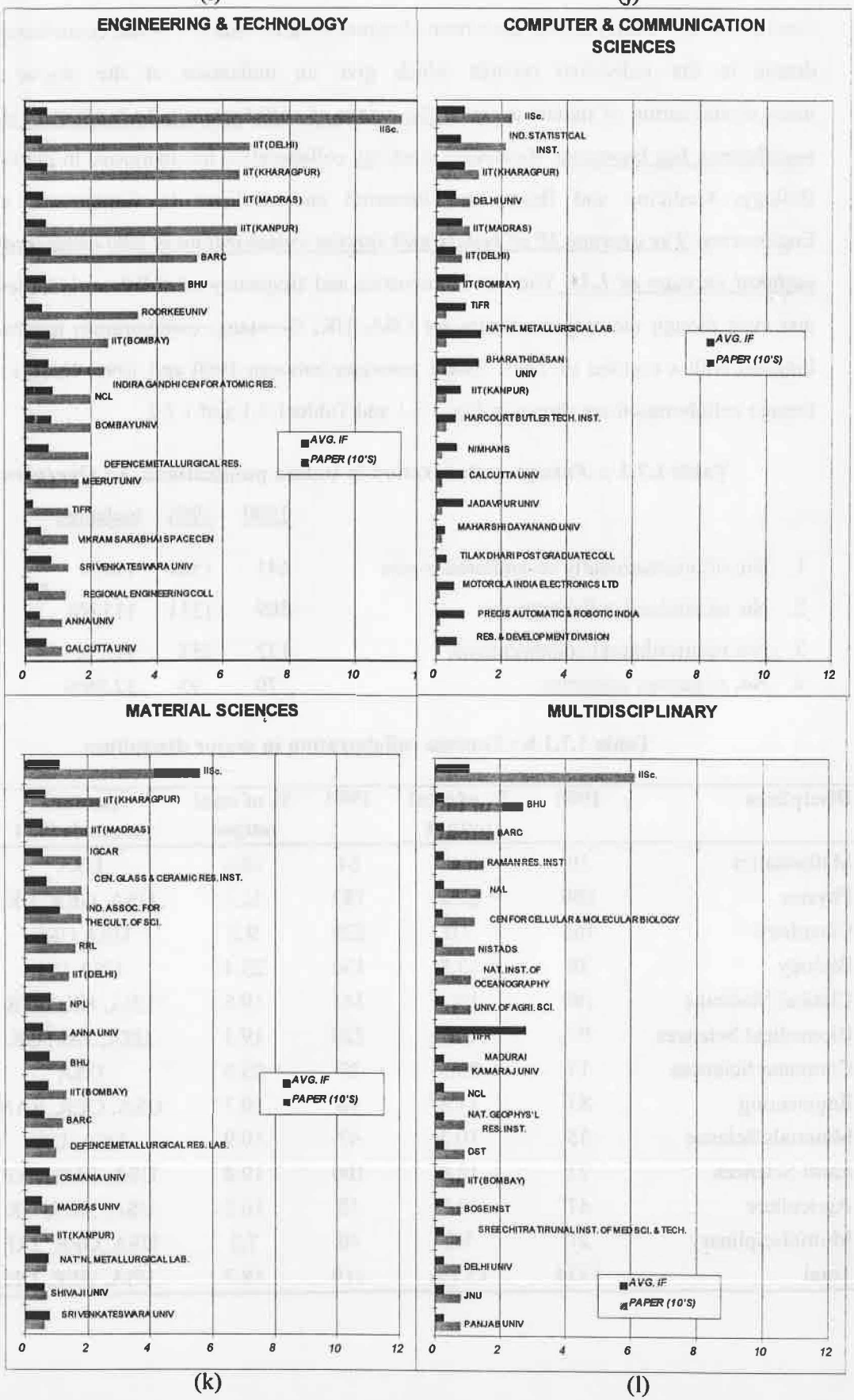
(e) (f)





(g) (h)

Fig 1.6.1 SCIENTIFIC PUBLICATION OUTPUT OF INDIAN INSTITUTIONS - 1994



1.7 Foreign Collaboration

Foreign collaboration patterns have been obtained from an analysis of the co-authorship details in the individual records which give an indication of the degree of internationalization of Indian science. ***The extent of collaboration, both bilateral and multilateral, has increased***. Relatively speaking, collaboration has increased in Physics, Biology, Medicine and Biomedical Research and declined in Computers, and Engineering. ***The average IF of papers with foreign collaboration is 2.06 compared to national average of 1.33.*** The list of countries and frequency of collaboration shows that even though the major partners are USA, UK, Germany, collaboration has been initiated with a number of Third World countries between 1990 and 1995. Details on foreign collaboration are shown in Fig. 1.7.1 and Tables1.7.1 and 1.7.2

Table 1.7.1 a :Foreign collaboration in Indian publications An Overview

	1990	1994	%change
1. No. of internationally co-authored papers	641	1564	144%
2. No. of bilateral collaborations	509	1311	155.6%
3. No. of multilateral collaborations.	132	253	91.7%
4. No. of partner countries	70	93	32.86%

Table 1.7.1 b : Foreign collaboration in major disciplines.

Disciplines	1990	% of total output	1994	% of total output	partner countries '94
Mathematics	50	29.8	54	28.6	USA
Physics	500	22.8	782	32.1	USA, GER, UK
Chemistry	165	7.0	228	9.2	USA,GER
Biology	78	13.8	130	23.4	USA,UK
Clinical Medicine	169	10.1	343	19.5	USA, UK, GER
Biomedical Sciences	97	11.0	220	19.1	USA, JAP, UK
Computer Sciences	17	33.3	27	23.9	USA
Engineering	83	11.8	98	10.7	USA, GER, CAN
Materials Science	35	10.3	47	10.9	USA, UK
Earth Sciences	72	18.6	100	19.8	USA, RUS, JAP
Agriculture	47	12.9	48	16.9	USA, AUS, UK
Multidisciplinary	21	5.0	40	7.3	USA, GER, JAP
Total	1334	13.2%	219	18.7	USA, GER, UK

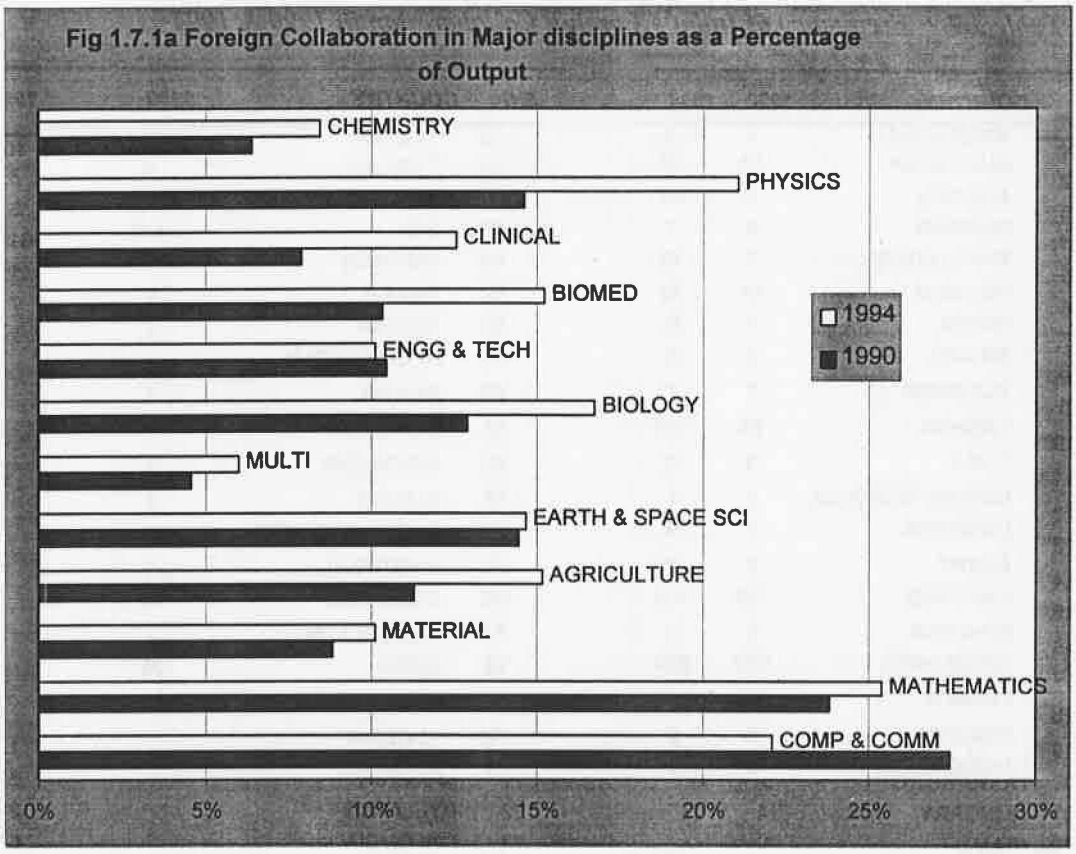


Fig 1.7.1a Foreign Collaboration in Major disciplines as a Percentage of Output
CHEMISTRY
PHYSICS
CLINICAL
BIOMED
ENGG & TECH
BIOLOGY
MULTI
EARTH & SPACE SCI
AGRICULTURE
MATERIAL
MATHEMATICS
COMP & COMM
1994
1990
0%
5%
10%
15%
20%
25%
30%

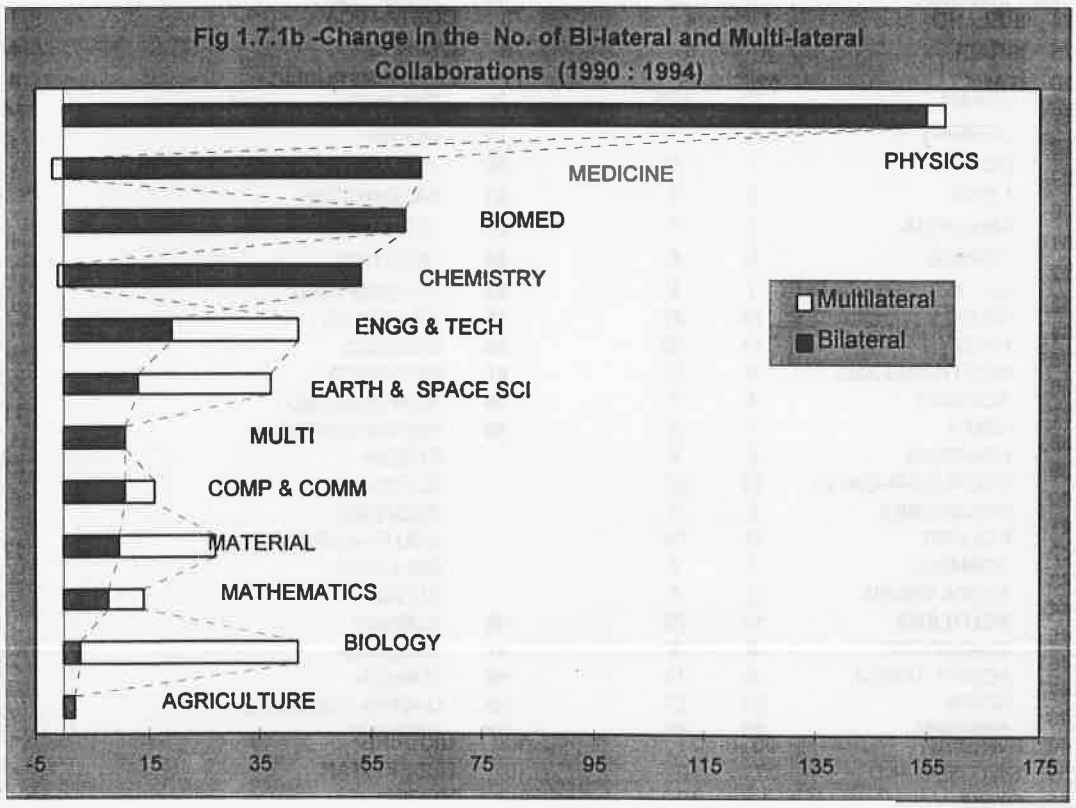


Fig 1.7.1b -Change in the No. of Bi-lateral and Multi-lateral Collaborations (1990 : 1994)
PHYSICS
MEDICINE
BIOMED
CHEMISTRY
ENGG & TECH
EARTH & SPACE SCI
MULTI
COMP & COMM
MATERIAL
MATHEMATICS
BIOLOGY
AGRICULTURE
Multilateral
Bilateral
-5
15
35
55
75
95
115
135
155
175

Table 1.7.2 Frequency of India's Foreign Collaboration in 1990 & 1994

	COUNTRY	1990	1994	S.No	COUNTRY	1990	1994
1	ARGENTINA	4	3	52	TAIWAN	2	10
2	AUSTRALIA	31	59	53	THAILAND	4	8
3	AUSTRIA	5	14	54	TURKEY	2	3
4	BAHRAIN	4	1	55	USA	441	611
5	BANGLADESH	7	15	56	VIETNAM	1	1
6	BELGIUM	11	18	57	WALES	9	7
7	BRAZIL	7	21	58	ZAMBIA	1	2
8	BRUNEI	1	5	59	AFGHANISTAN	1	
9	BULGARIA	7	7	60	ARABIA	1	
10	CANADA	74	122	61	BERMUDA	1	
11	CHILE	3	8	62	INDONESIA	1	
12	CZECHOSLOVAKIA	4	1	63	KUWAIT	4	
13	DENMARK	7	9	64	PAPUA-N-GUINEA	2	
14	EGYPT	3	7	65	PORTUGAL	1	
15	ENGLAND	119	169	66	ZIMBABWE	4	
16	ETHIOPIA	2	3	67	YUGOSLAVIA	1	
17	GERMANIES	135*	204	68	USSR	25	
18	FRANCE	52	109	69	FINLAND	5	
19	GREECE	5	9	70	ALGERIA		1
20	HONG-KONG	3	2	71	ARMENIA		3
21	HUNGARY	14	15	72	BYELARUS		2
22	IRAN	3	2	73	COLOMBIA		6
23	IRAQ	1	2	74	CONGO		2
24	IRELAND	1	4	75	COSTA-RICA		1
25	ISRAEL	3	8	76	CYPRUS		4
26	ITALY	52	85	77	CZECH-REPUBLIC		4
27	JAPAN	73	125	78	FINLAND		14
28	JORDAN	3	1	79	GHANA		1
29	KENYA	1	6	80	JAMAICA		1
30	LIBYA	2	3	81	KAZAKHSTAN		3
31	MALAYSIA	1	7	82	LEBANON		1
32	MEXICO	5	6	83	LESOTHO		1
33	NEPAL	1	3	84	LUXEMBOURG		1
34	NETHERLANDS	29	32	85	MAURITIUS		1
35	NIGERIA	11	10	86	MONACO		1
36	NORTH-IRELAND	3	17	87	MOROCCO		2
37	NORWAY	4	7	88	NEW-ZEALAND		11
38	OMAN	1	3	89	REP-OF-GEORGIA		1
39	PAKISTAN	3	4	90	RUSSIA		52
40	PEOPLES-R-CHINA	19	22	91	SLOVAKIA		4
41	PHILIPPINES	5	7	92	SLOVENIA		1
42	POLAND	6	14	93	SOUTH-KOREA		12
43	ROMANIA	3	7	94	SRI-LANKA		3
44	SAUDI-ARABIA	2	3	95	SUDAN		1
45	SCOTLAND	12	20	96	SURREY		1
46	SINGAPORE	3	5	97	TANZANIA		2
47	SOUTH-AFRICA	4	10	98	TUNISIA		3
48	SPAIN	21	27	99	U-ARAB-EMIRATES		7
49	SWEDEN	20	31	100	UKRAINE		1
50	SWITZERLAND	37	32	101	UZBEKISTAN		4
51	SYRIA	1	12	102	YEMEN		1

* - *FRG - 126, GDR - 9*

1.8 Interstate Collaboration

Interstate collaboration patterns show that more states have entered the collaborative network between 1990 and 1994. A collaborative network of states showing links greater than the average density of links is drawn below.

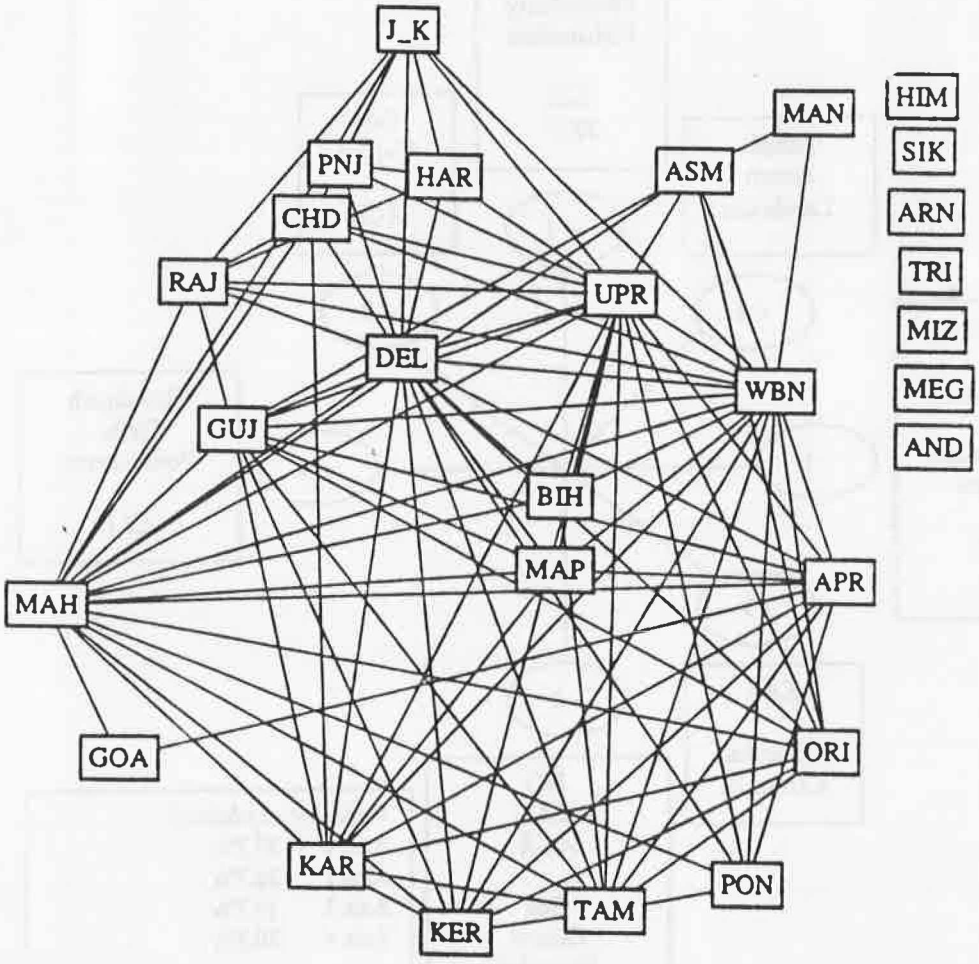


Fig 1.8 Network of Scientific Co-operation of Indian States (1994)

1.9 Structural Analysis

The structure of multivariate relationships between states and fields may be visualized from the infographic maps, which summarise the results of Correspondence Analysis on the output of 28 states in 12 disciplines. The details of the correspondence analysis are in Chapter 10. The overall structure of relationships between states and research fields has not changed very much in the interval between 1990 and 1994. While the hard core of the matrix has remained intact, non trivial changes in the case of the relatively smaller states have been observed.

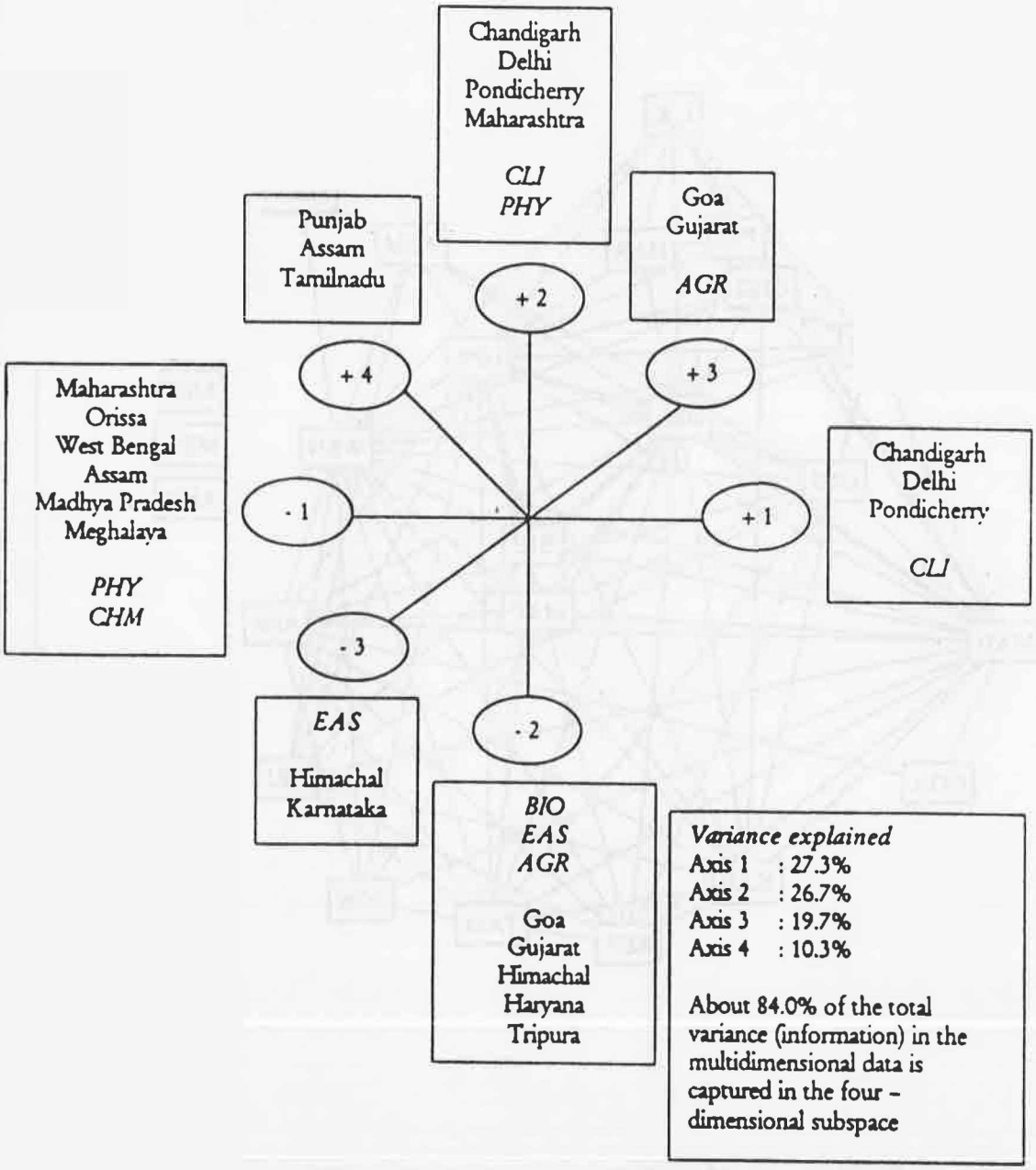


Fig 1.9 Summary of Correspondence Analysis (1994 data)

1.10 Conclusions

In this study, we have tried to indicate that it is possible to use bibliometric analysis to project a detailed picture of various aspects of national scientific activity including output, impact, change and foreign and domestic collaboration from the publication data alone.

The analysis at the level of institutions was beyond the scope of this study. However we included a few of the details which may be of interest to a wider scientific community.

More useful information can be generated if the indicators of scientific output are combined with existing indicators of inputs such as manpower or funds. This can form the basis of a system of evaluation that is non invasive, within the known limitations of bibliometric studies.

Like all other 'remotely sensed' information it needs to be confirmed by 'ground truth'; in other words, the opinion of subject experts need to be taken into account in the final interpretations.

A word needs to said about future work in this direction. A proper bibliometric analysis will require the analysis of citations as well as necessitate the building up of a database of publications for several years from which short and long term trends may be mapped.

2 Introduction

Information on inputs to the scientific establishment (i.e. financial, manpower employed etc.), as well as outputs (i.e. publications, patents, manpower trained, etc.) is an essential adjunct to discussions on science policy or decision making in science. While input statistics are regularly compiled and made available, output statistics have to be generated from dispersed data. Unless compiled on a routine basis (e.g. by the patent office, or UGC) these statistics are not readily available. Compilation of India's publication record is a painstaking exercise which has been partially undertaken in the form of the *Indian Science Abstracts* at INSDOC. As yet no comprehensive attempts have been made to map India's scientific output using this data. Moreover the ISA leaves out a significant proportion of Indian papers appearing in foreign journals.

The *Science Citation Index*, brought out annually by the *Institute of Scientific Information, Inc.*, (USA) therefore remains the database of choice, providing world wide data on published scientific papers and access to author names, titles, sources, references cited and author addresses, from about 4000 journals in all fields of science. Designed originally as a research tool, it has of late been used by several countries to monitor internationally visible scientific output. *ISI* claims to select journals on the basis of their citation levels. Since 1987, the SCI has covered about 12 Indian journals, a decline from about 40 journals covered in 1979. At present (1994) India's publications in the SCI from the Indian journals is about 12 percent. The remaining Indian papers, are in international journals published outside India.

Without going into debates on whether the coverage of journals from India (and thereby a substantial part of India's scientific output) is adequate, we have proceeded with the exercise of examining Indian publications in the SCI for the years 1990 and 1994, with a view to map output and changes in the scientific disciplines at the national, sectoral and state levels. Unlike other analyses (e.g. ISSRU, Hungary) that attribute a paper only to

the country of the first author, we have included all papers with at least one author from India.

A total of a little over 20,000 records with at least one corporate address from India was retrieved from the 1990 & 1994 editions of SCI and converted into a database. The data was cleaned to standardize names of corporate addresses. Impact Factors from the *Journal Citation Reports* (JCR), and country of publication from Ulrich directory, were introduced manually. The journals were then categorized into 11 major scientific disciplines and a 'multidisciplinary' category to incorporate journals that include papers in all disciplines (ie. Nature, Current Science). This scheme provides the basis for the classification of individual papers.

The structured database was then used to answer the following questions, i.e.

- which were the journals in which Indian scientists published
- what was the number of scientific publications in major disciplines and subdisciplines in 1990 & 1994?
- the average impact factor of publications in each discipline.
- sectoral output in each disciplinary category in both years.
- state level output in each of the 12 disciplinary categorise.
- changes between 1990 & 1994.

These issues are covered in Chapters 4-8

The SCI lists the addresses of all authors of a paper and thus provides a unique opportunity to study collaboration patterns. Using this, we have extracted (Chapter 9),

- foreign and interstate collaboration
- changes between 1990 and 1994

2.1 Multivariate Analysis :

There are two sources of noise in the data used. One is the random year to year fluctuation that cannot be detected in a simple 2-time period study. This may be overcome by aggregating data over a few years to smooth fluctuations. The other source of noise is introduced by the classification procedure. Inevitably, some articles will be wrongly classified due to the fact that journal interests span intersections between disciplines. Multivariate analyses of the data (Correspondence Analysis and Network Analysis) help reveal underlying patterns and similarities, suppressing the effects of noise. (Chapters 10 and 11).

2.2 Citation Analysis :

In the past, one of the main uses of the Science Citation Index has been the analysis of citations received by individual papers which gives an index of the utility of these papers in ongoing research. However, this entails an analysis of citation matched data from across the world. In this study, citation analysis has not been attempted as the level of computer hardware support, data access, time and manpower requirements exceed the outlay for the present exploratory exercise. It is hoped that such an analysis shall constitute the basis for a future study.

3 Methodology

The publications from the *SCI* database were selected as being Indian on the basis of the geographical location in India of any of the authors In the present study, data for the years 1990 and 1994 have been taken from the Science Citation Index for a detailed analysis. This contained a little over 20,000 individual publications with at least one address originating in India. The data were converted into a database using the software package FOXPRO.

3.1 Data Pre Processing

3.1.1 Enhancement

The SCI includes information on author names, title, journal, document type, author addresses, language and references. This has been enhanced by appending the 'impact factor' (IF) of the journal from the Journal Citation Report (JCR) of 1994, and the country of publication of the journal from Ulrich directory.

3.1.2 Data Cleaning and Standardization

The data had to be cleaned to remove multiple forms of the same institutional addresses and reduce addresses to a standard form. This was partially done by computerised recognition algorithms.

3.2 Document Type

ISI categorizes papers by type. Documents have been classified into 8 types as Article, Note, Review, Biographical Item, Letter, Editorial, Correction and Meeting Abstracts. All types of documents have been included in this study.

The number of articles, reviews, letters meeting abstracts, notes from India vary considerably, the bulk of the output being in the form of research articles and notes. Impact Factor is seen to vary according to the nature of the document. While the bulk of the papers lay within an impact factor range of 0-5, a small percentage of articles had impacts in the range 10-40. A higher percentage of letters appeared in journals with IF > 15-25. A few reviews appeared in journals with IF between 10-15. Meeting abstracts had a larger proportion of high IF documents, the highest value ranging to 60.

3.3 Classification into Subfields

The articles were classified into disciplinary categories using a procedure followed by Computer Horizons Inc. (CHI), and developed in Nagpaul (1997).

The journals have been classified into 12 classes, comprising 11 major disciplines, given below, and a separate multidisciplinary category.

Mathematics	Physics
Chemistry	Biology
Agriculture	Clinical Medicine
Biomedical Sciences	Computer Sciences
Engineering	Materials Science
Earth Sciences	Multidisciplinary

3.4 Journals used

The journals covered by SCI and used by Indian scientists have been ranked in terms of their usage and Impact factor. The Indian journals included in SCI do not appear to have high impact factors . A full list of journals is appended in Part II (Table 2).

3.5 Performance Indicators

The performance of agencies, regions, institutions are obtained in terms of total output of papers in 12 disciplines and the 'impact factor' of the journals carrying the publication. Comparisons are made with the national averages. Indicators used to enable comparisons e.g. of state activity and impact in different disciplines on the basis of the national activity and impact profiles, are defined below:

3.5.1 Impact factor

of a journal is defined as the ratio of

number of citations to a journal in a given year / number of publications in the previous two years.

3.5.2 Average Impact Factor

is defined as

Total Impact factor of all papers / Total number of papers

3.5.3 Activity Index

of a state is defined as

Fraction of papers in a given discipline by state/ Fraction of papers in the same discipline in the country.

3.5.4 Visibility Index

of ***X***(state/institution/sector) in a given discipline ***Y*** is defined as

Fraction of cumulative impact of papers from the state in the discipline / Fraction of cumulative impact of total country papers in the same discipline

These indices enable comparison between both states and disciplines. However the values cease to be meaningful if some of the quantities being normalized are small [7]. This problem becomes more acute as the unit of analysis becomes smaller. The indices are therefore not computed below the state level.

3.6 Collaboration Patterns

Since the *SCI* gives addresses of all authors, it is possible to infer the extent of international as well as national collaboration. A study on Transnational collaboration in Indian science based on the SCI had been conducted by Nagpaul, (1997), where the extent of India's foreign collaboration was compared with that of other countries. In this study we have not made any international comparisons. In Chapter 9 we indicate the levels of foreign collaboration, both bilateral and multilateral, in all fields of science in the -years 1990 and 1994, and the major partner countries in collaboration.

3.7 Structural Analysis

The structure of output of the 28 states in 12 fields of science is difficult to visualise in terms of the raw data. Are certain states similar to others in terms of their research activities? These similarities can be revealed through Correspondence Analysis. The procedure is a data reduction technique by which data on links in a 28*11 dimensional space is reduced to approximately 3 dimensions which can be displayed as 2 dimensional graphs. The distance between the points (states as well as disciplines) indicates the relative position of each state with respect to a discipline.

3.8 Network Analysis

Techniques of network analysis have been used to determine the 'centrality' of the network of inter-state collaboration. This gives an estimate of whether the network is dominated by a few actors (states). The centrality of each of the actors also indicates the position of the actor in the network, i.e. its strength of interaction with respect to co-authorship links and extent of linkages in terms of number of partners with which it is involved. Actors whose links fall below the average density of links are shown as isolates. The data can also be reduced to a block model where the states are grouped into blocks reflecting their intrinsic similarities.

3.9 Citations

Citations have not been considered in this study. Since citations provide an important indication of the utility of a research work, we hope to include citation levels in a later study which would indicate references being cited by Indian authors.

3.10 Limitations of the Study

A study of this nature, inevitably suffers from several limitations. The data is subject to year to year fluctuations thereby making it impossible to state whether observed changes are a random effect or indicating an actual underlying trend. Other limitations are listed below.

3.10.1 Multiple Counts

Where more than one address appears in a paper, there is a possibility of multiple counts. For example a joint paper with authors from two separate institutions is included in the output of both institutions. Similarly joint papers with interstate collaboration result in multiple counting of papers when the output of states is aggregated. Wherever possible, one should try to estimate the effect of multiple counts in terms of the *Redundancy Factor*.

3.10.2 Redundancy Factor

The redundancy factor estimates the effect of multiple counts in terms of the excess over the actual number of papers, as a proportion of the number of papers.

3.10.3 Unidentified Addresses and Excluded Cases

About 70 address could not be identified with standard institutional names. In addition there were about 0.2 per cent- papers from private addresses. These have not been included except for computation of national averages. In certain instances institutions with very low annual output have been excluded.

4 Journals used by Indian Scientists

This chapter examines the journals or periodicals publishing papers from India.

4.1 Country of Publication and Impact Factor

SCI obtains an Impact Factor (IF) for each journal based on its citation rate. The IF of a journal is usually defined as the ratio of the citations received by a journal in a given year to articles published in the previous two years. While this does give an indication of visibility of the journals, it does not take into account differences in citation pattern between disciplines. Thus direct comparisons across disciplines cannot be made using the journal impact factors.

The list of journals in the SCI data on Indian publications in 1990 and 1994 are not identical. They have been combined to obtain an approximate number of journals for the years 1990 and 1994. The number of papers and journals, and average number of papers in periodicals from different countries are shown in Table 4.1. The country of publication has been obtained from the Ulrich directory of periodicals. Almost one quarter of all papers from India in the SCI appeared in American journals. As expected, Indian journals published, on an average, the highest number of Indian papers (>100 articles per journal). Aside from this, the highest average number appeared in international journals published from Hungary, Czechoslovakia, Romania and the Netherlands (Fig 4.1)

The rank of the journal by frequency of use was usually inversely correlated with the rank by Impact Factor. Some exceptions have been noted in different disciplines. The top journals in any field ranked both by frequency of use and by Impact factor are listed in Table 4.3. A full list of journals with Impact factors is given in Part II (Table 2).

PUB_COUNT

TABLE 4.1

INDIAN PAPERS IN JOURNALS PUBLISHED FROM DIFFERENT COUNTRIES

COUNTRY	JOURNALS 90 - 94	PAPERS 94	PAPERS 90	AVG. PAPERS 94	AVG. PAPERS 90
USA	863	4244	3429	4.9	4.0
UKD	341	1537	1580	4.5	4.6
IND	13	1382	1413	106.3	108.7
NLD	191	1178	1295	6.2	6.8
GER	112	491	556	4.4	5.0
SWZ	73	430	361	5.9	4.9
JPN	49	153	146	3.1	3.0
AUS	21	103	40	4.9	1.9
DNK	27	96	132	3.6	4.9
CSK	9	69	68	7.7	7.6
IRL	14	68	94	4.9	6.7
FRA	36	66	69	1.8	1.9
CAN	25	65	86	2.6	3.4
HUN	10	61	114	6.1	11.4
ITA	15	36	49	2.4	3.3
POL	9	34	23	3.8	2.6
ROM	2	27	6	13.5	3.0
SWE	11	17	18	1.5	1.6
AUT	3	14	15	4.7	5.0
ISR	4	9	8	2.3	2.0
BEL	4	6	9	1.5	2.3
PRC	3	4	2	1.3	0.7
SUN	4	3	1	0.8	0.3
NOR	1	2	1	2.0	1.0
FIN	1	1	2	1.0	2.0
FRL	1	1	0	1.0	0.0
MEX	1	1	0	1.0	0.0
PAK	1	1	0	1.0	0.0
KWT	1	0	1	0.0	1.0
NZL	2	0	5	0.0	2.5
SGP	1	0	1	0.0	1.0
UKA	1	0	1	0.0	1.0
OTHERS	297	1215	578	4.1	1.9
TOTAL	2146	11314	10103	5.3	4.7

4.2 Indian Journals

Since 1987, the number of Indian journals covered by the SCI has been about twelve, - a steep fall from forty journals before 1980. About 1382 papers in 1994 were published in Indian journals declining slightly from a figure of 1413 in 1990. This gives an average figure of more than 100 papers per year in Indian journals. As expected this is an order of magnitude higher than the average number of Indian publications in journals of any other country.

The list of Indian journals covered by SCI is shown in Table 4.2. The Impact Factor of all of them lie below 1. There are two Multidisciplinary journals and two each in Physics, Clinical Medicine and Biomedical Research. In Chemistry there as 3 journals and one in Earth & Space Sciences. In the remaining areas (Engineering, Computers, Mathematics, Biology and Agriculture) there are no Indian journals covered by SCI. The journal with the highest IF is the journal of Astronomy & Astrophysics, with an IF of 0.71. Only two Indian journals are not among the highly used journals within their discipline namely Astronomy & Astrophysics and Journal of Genetics (rank by use > 10).

4.3 International Journals

The largest number of journals used by Indian authors are published in the USA, UK, Netherlands and Germany. Between 1990 and 1994, the papers increased significantly in journals published in USA, and less so in Switzerland and Australia. In journals from Netherlands, Germany, Hungary, UK, Indian publications have declined. The country of publication of about 300 journals could not be identified (Fig.4.1).

Journals which fall within the top ten both in rankings by IF and use are *Abstracts of the American Chemical Society (IF=8.0), FASEB Journal (IF=15.1) Journal of Agriculture and Food Chemistry* (IF = 1.3). *Theriogenology* (IF = 1.97), *Lancet* (IF = 17.3) *Journal of Biological Chemistry* (IF = 7.7), *Journal of Chemical Information and Computer Science* (IF = 1.8), *Computers and Chemistry (IF=1.4), Journal of Materials Research* (IF = 2), *International Journal for Numerical Methods in Engineering* (IF = 1) and six multidisciplinary journals with IF ranging from 25.5 for *Nature* and 22.1 for *Science* to 0.5 for *Science Progress*.

Table 4.2 : List of Indian Journals Occurring in the SCI Data for 1990 & 1994

FIELD & JOURNAL TITLE	IF	1990	1994	TOTAL	RANK/IF	RANK/USE
PHYSICS						
JOURNAL OF ASTROPHYSICS AND ASTRONOMY	0.706	23	19	42	151	32
PRAMANA-JOURNAL OF PHYSICS	0.345	109	117	226	192	1
CHEMISTRY						
PROCEEDINGS OF THE INDIAN ACADEMY OF SCIENCES-CHEMICAL SCIENCES	0.000	83	70	153	187	5
INDIAN JRL OF CHEM SEC A-INORGANIC BIO-INORGANIC PHYS THEORETICAL & ANALYTICAL CHEM	0.355	309	177	486	172	2
INDIAN JOURNAL OF CHEMISTRY SECTION B-ORGANIC CHEMISTRY INCLUDING MEDICINAL CHEM	0.293	268	299	567	175	1
EARTH & SPACE SCIENCES						
PROCEEDINGS OF THE INDIAN ACADEMY OF SCIENCES-EARTH AND PLANETARY SCIENCES	0.000	35	24	59	115	3
CLINICAL MEDICINE						
INDIAN JOURNAL OF MEDICAL RESEARCH	0.296	96	97	193	539	1
INDIAN JRL OF MEDICAL RES SECTION B-BIOMEDICAL RES OTHER THAN INFECTIOUS DISEASES	0.175	73	9	82	557	3
BIO-MEDICAL RESEARCH						
JOURNAL OF BIOSCIENCES	0.432	34	41	75	249	1
JOURNAL OF GENETICS	0.389	8	9	17	255	27
MULTI-DISCIPLINARY						
CURRENT SCIENCE	0.271	334	461	795	13	1
JOURNAL OF SCIENTIFIC & INDUSTRIAL RESEARCH	0.237	41	59	100	14	2

Total number of Indian Journals occurring in the SCI Data is twelve. No Indian Journal features in the fields of Mathematics, Biology, Agriculture, Engineering & Technology, Computers & Communication Sciences and Material Sciences.

FIG 4.1 INDIAN PUBLICATION IN INTERNATIONAL JOURNALS
(BY COUNTRY OF PUBLICATION)

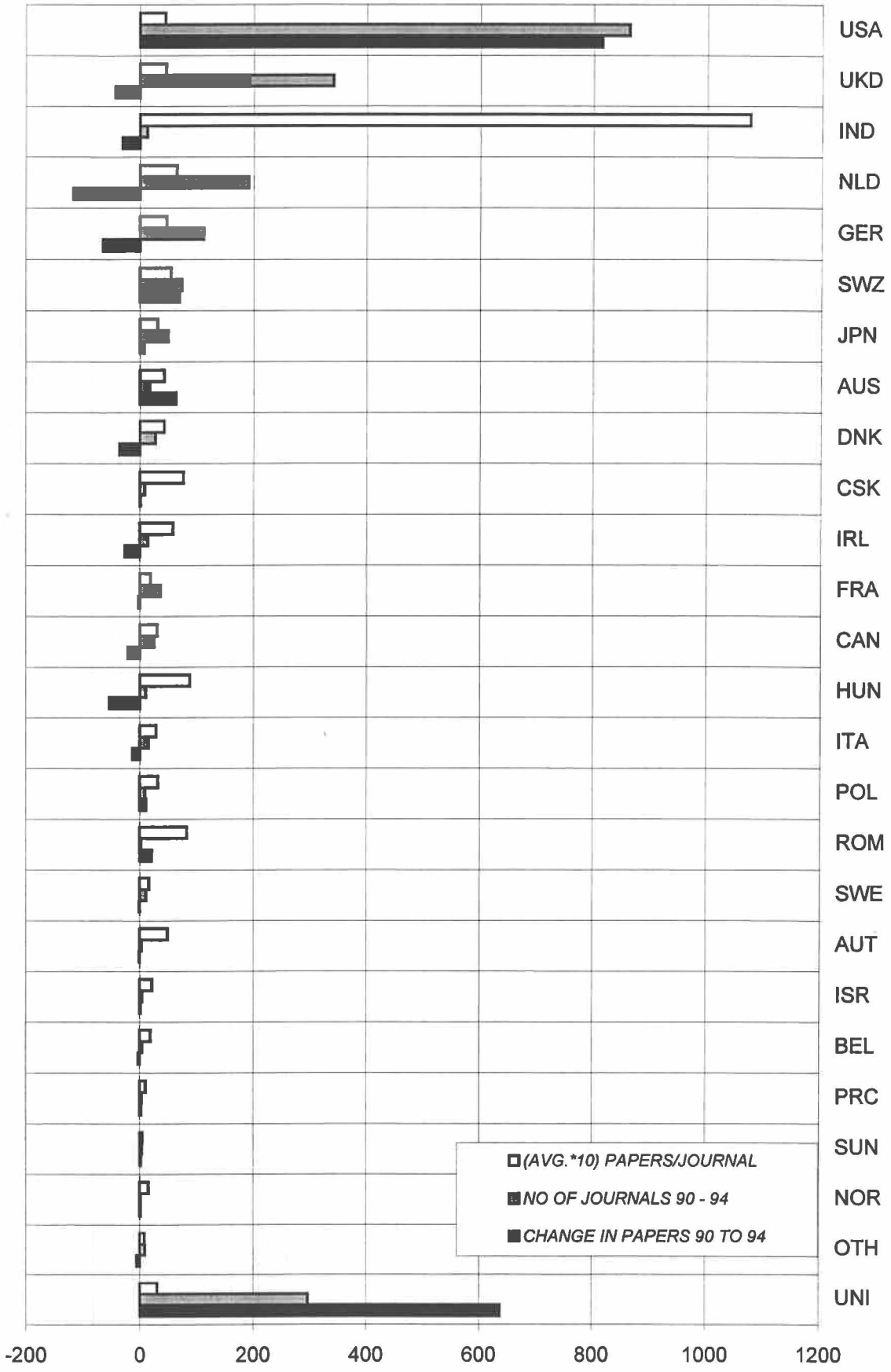


Table 4.3: Journals carrying Indian Papers ranked by IF and use

Jtable1

MATHEMATICS

JOURNAL TITLE	IF	COUNTRY	1990	1994	TOTAL	RANK/IF	RANK/USE
IF Rankings							
JOURNAL OF THE ROYAL STATISTICAL SOCIETY SERIES B-METHODOLOGICAL	2.538	UKD	0	2	2	1	35
NONLINEARITY	1.474	UKD	2	0	2	2	35
ANNALS OF MATHEMATICS	1.449	USA	1	1	2	3	35
JOURNAL OF THE AMERICAN STATISTICAL ASSOCIATION	1.244	USA	0	1	1	4	59
SIAM REVIEW	1.216	USA	1	0	1	5	59
AMERICAN STATISTICIAN	1.160	USA	0	1	1	6	59
SIAM JOURNAL ON NUMERICAL ANALYSIS	1.021	USA	2	1	3	7	25
INTERNATIONAL JOURNAL FOR NUMERICAL METHODS IN ENGINEERING	1.002	UKD	5	5	10	8	4
SIAM JOURNAL ON MATRIX ANALYSIS AND APPLICATIONS	1.000	USA	2	1	3	9	25
INVERSE PROBLEMS	0.980	UKD	0	1	1	10	59
Contribution Rankings							
JOURNAL OF MATHEMATICAL ANALYSIS AND APPLICATIONS	0.339	USA	19	29	48	63	1
FUZZY SETS AND SYSTEMS	0.610	NLD	13	34	47	32	2
LINEAR ALGEBRA AND ITS APPLICATIONS	0.430	USA	10	12	22	51	3
INTERNATIONAL JOURNAL FOR NUMERICAL METHODS IN ENGINEERING	1.002	UKD	5	5	10	8	4
JOURNAL OF THE AUSTRALIAN MATHEMATICAL SOCIETY SERIES B-APPLIED MATH	0.450	AUS	3	7	10	49	4
JOURNAL OF ALGEBRA	0.468	USA	4	4	8	47	6
JOURNAL OF OPTIMIZATION THEORY AND APPLICATIONS	0.316	USA	5	3	8	66	6
APPLIED MATHEMATICS AND COMPUTATION	0.241	USA	6	2	8	77	6
BIOMETRIKA	0.832	UKD	4	3	7	15	9
JOURNAL OF THE OPERATIONAL RESEARCH SOCIETY	0.546	UKD	3	4	7	39	9
COMMUNICATIONS IN ALGEBRA	0.288	USA	3	4	7	70	9
OPERATIONS RESEARCH LETTERS	0.235	NLD	3	4	7	79	9
PROCEEDINGS OF THE ROYAL SOCIETY OF LONDON SERIES A-MATH & PHYS SCI	0.000	UKD	3	4	7	84	9

The shaded journals are the ones occurring in both the rankings.

PHYSICS

JOURNAL TITLE	IF	COUNTRY	1990	1994	TOTAL	RANK/IF	RANK/USE
IF Rankings							
REVIEWS OF MODERN PHYSICS	14.426	USA	1	1	2	1	168
REPORTS ON PROGRESS IN PHYSICS	6.727	UKD	1	0	1	2	182
PHYSICAL REVIEW LETTERS	6.626	USA	19	37	56	3	21
PHYSICS REPORTS-REVIEW SECTION OF PHYSICS LETTERS	6.541	NLD	3	2	5	4	130
PROGRESS IN NUCLEAR MAGNETIC RESONANCE SPECTROSCOPY	5.750	USA	1	0	1	5	182
MASS SPECTROMETRY REVIEWS	4.160	USA	1	0	1	6	182
NUCLEAR PHYSICS B	3.722	NLD	13	14	27	7	46
JOURNAL DE CHIMIE PHYSIQUE ET DE PHYSICO-CHIMIE BIOLOGIQUE	3.635	FRA	2	0	2	8	168
JOURNAL OF CHEMICAL PHYSICS	3.635	USA	15	35	50	8	26
ASTROPHYSICAL JOURNAL *	3.544	USA	3	2	5	10	130
Contribution Rankings							
PRAMANA-JOURNAL OF PHYSICS	0.345	IND	109	117	226	192	1
PHYSICAL REVIEW B-CONDENSED MATTER	3.187	USA	76	130	206	15	2
PHYSICAL REVIEW A	2.292	USA	72	66	138	35	3
JOURNAL OF APPLIED PHYSICS	1.658	USA	63	68	131	65	4
SOLID STATE COMMUNICATIONS	1.446	USA	70	60	130	84	5
ASTROPHYSICS AND SPACE SCIENCE	0.310	NLD	84	24	108	201	6
PHYSICAL REVIEW D	3.233	USA	38	70	108	13	7
PHYSICA C	3.258	NLD	50	54	104	12	8
JOURNAL OF PHYSICS-CONDENSED MATTER	1.562	UKD	49	51	100	71	9
PHYSICA STATUS SOLIDI B-BASIC RESEARCH	0.733	GER	48	46	94	149	10
PHYSICS LETTERS A	1.228	NLD	45	49	94	104	10

The shaded journals are the ones occurring in both the rankings.

CHEMISTRY

JOURNAL TITLE	IF	COUNTRY	1990	1994	TOTAL	RANK/IF	RANK/USE
IF Rankings							
CHEMICAL REVIEWS	14.240	USA	3	3	6	1	116
INORGANIC SYNTHESES	11.600	USA	1	0	1	2	166
ABSTRACTS OF PAPERS OF THE AMERICAN CHEMICAL SOCIETY	8.000	USA	44	46	90	3	10
ANGEWANDTE CHEMIE-INTERNATIONAL EDITION IN ENGLISH	6.327	GER	0	4	4	4	132
APPLIED CATALYSIS B-ENVIRONMENTAL	6.319		0	1	1	5	166
JOURNAL OF THE AMERICAN CHEMICAL SOCIETY	5.039	USA	9	10	19	6	59
CHEMICAL SOCIETY REVIEWS	4.913	UKD	0	1	1	7	166
NATURAL PRODUCT REPORTS	4.906	UKD	0	1	1	8	166
ANALYTICAL CHEMISTRY	4.609	USA	0	3	3	9	143
TOPICS IN CURRENT CHEMISTRY	4.000	USA	0	1	1	10	166
Contribution Rankings							
INDIAN JOURNAL OF CHEMISTRY SECTION B-ORGANIC CHEMISTRY INCLUDING MEDICINAL CHEM	0.293	IND	268	299	567	175	1
INDIAN JRL OF CHEM SEC A-INORGANIC BIO-INORGANIC PHYS THEORETICAL & ANALYTICAL CHEM	0.355	IND	309	177	486	172	2
JOURNAL OF APPLIED POLYMER SCIENCE	0.870	USA	86	101	187	108	3
TETRAHEDRON LETTERS	2.378	USA	70	90	160	24	4
PROCEEDINGS OF THE INDIAN ACADEMY OF SCIENCES-CHEMICAL SCIENCES	0.000	IND	83	70	153	187	5
SYNTHESIS AND REACTIVITY IN INORGANIC AND METAL-ORGANIC CHEMISTRY	0.442	USA	61	69	130	157	6
SYNTHETIC COMMUNICATIONS	0.699	USA	76	41	117	129	7
TETRAHEDRON	2.277	USA	39	62	101	27	8
POLYHEDRON	1.081	USA	37	57	94	88	9
ABSTRACTS OF PAPERS OF THE AMERICAN CHEMICAL SOCIETY	8.000	USA	44	46	90	3	10

The shaded journals are the ones occurring in both the rankings.

BIOLOGY

JOURNAL TITLE	IF	COUNTRY	1990	1994	TOTAL	RANK/IF	RANK/USE
IF Rankings							
FASEB JOURNAL	15.115	USA	0	22	22	1	9
BIOESSAYS	6.017	UKD	0	1	1	2	126
PROTEIN SCIENCE	4.856		0	2	2	3	93
ECOLOGICAL MONOGRAPHS	4.838	USA	0	1	1	4	126
CRITICAL REVIEWS IN PLANT SCIENCES	4.146		2	0	2	5	93
ANNUAL REVIEW OF PHYTOPATHOLOGY	4.106	USA	1	0	1	6	126
TRENDS IN ECOLOGY & EVOLUTION	4.106		0	1	1	6	126
BOTANICAL REVIEW	3.946	USA	0	2	2	8	93
ADVANCES IN MARINE BIOLOGY	3.714	USA	0	1	1	9	126
PLANT PHYSIOLOGY	3.542	USA	3	6	9	10	27
Contribution Rankings							
PHYTOCHEMISTRY	1.157	USA	71	68	139	44	1
ANNALS OF APPLIED BIOLOGY	0.405	UKD	18	37	55	127	2
EUPHYTICA	0.579	NLD	25	24	49	103	3
PHOTOSYNTHETICA	0.457	CSK	20	16	36	117	4
PLANT CELL REPORTS	1.590	USA	12	22	34	30	5
PLANT SCIENCE	1.257	IRL	17	11	28	39	6
JOURNAL OF NATURAL PRODUCTS-LLOYDIA	1.498	USA	13	10	23	32	7
MYCOPATHOLOGIA	1.050	NLD	11	12	23	51	7
FASEB JOURNAL	15.115	USA	0	22	22	1	9
ANNALS OF BOTANY	1.066	UKD	18	2	20	50	10
MYCOLOGICAL RESEARCH	0.975		11	9	20	57	10
PLANT CELL TISSUE AND ORGAN CULTURE	0.745	NLD	9	11	20	84	10

The shaded journals are the ones occurring in both the rankings.

EARTH AND SPACE SCIENCES

JOURNAL TITLE	IF	COUNTRY	1990	1994	TOTAL	RANK/IF	RANK/USE
IF Rankings							
METEORITICS	4.067	USA	5	7	12	1	18
EARTH AND PLANETARY SCIENCE LETTERS	2.951	NLD	2	6	8	2	29
ENVIRONMENTAL AND MOLECULAR MUTAGENESIS	2.847	USA	1	1	2	3	81
GEOCHIMICA ET COSMOCHIMICA ACTA	2.831	USA	3	2	5	4	46
EARTH-SCIENCE REVIEWS	2.667	NLD	0	1	1	5	99
CONTRIBUTIONS TO MINERALOGY AND PETROLOGY	2.319	USA	1	2	3	6	68
LIMNOLOGY AND OCEANOGRAPHY	2.151	USA	1	0	1	7	99
GEOPHYSICAL RESEARCH LETTERS	2.145	USA	4	9	13	8	17
GEOLOGY	2.053	USA	1	3	4	9	53
MARINE MICROPALEONTOLOGY	1.908	NLD	1	0	1	10	99
Contribution Rankings							
BULLETIN OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY	0.000	USA	47	39	86	115	1
INTERNATIONAL JOURNAL OF REMOTE SENSING	0.882	UKD	14	53	67	66	2
PROCEEDINGS OF THE INDIAN ACADEMY OF SCIENCES-EARTH AND PLANETARY SCIENCES	0.000	IND	35	24	59	115	3
JOURNAL OF ENVIRONMENTAL SCIENCE AND HEALTH PART A-ENVIRONMENTAL SCI & ENG	0.467	USA	11	13	24	91	4
JOURNAL OF ATMOSPHERIC AND TERRESTRIAL PHYSICS	0.892	USA	7	16	23	65	5
MARINE GEOLOGY	1.061	NLD	10	11	21	57	6
ENVIRONMENTAL CONSERVATION	0.371	SWZ	4	17	21	103	6
ENVIRONMENTAL POLLUTION	1.159	UKD	10	10	20	48	8
ATMOSPHERIC ENVIRONMENT PART A-GENERAL TOPICS	1.310		16	0	16	36	9
ECOTOXICOLOGY AND ENVIRONMENTAL SAFETY	1.290	USA	11	5	16	38	9
WATER AIR AND SOIL POLLUTION	0.841	NLD	12	4	16	70	9

The shaded journals are the ones occurring in both the rankings.

AGRICULTURE

JOURNAL TITLE	IF	COUNTRY	1990	1994	TOTAL	RANK/IF	RANK/USE

IF Rankings

THERIOGENOLOGY	1.967	USA	11	6	17	1	10
PESTICIDE BIOCHEMISTRY AND PHYSIOLOGY	1.851	USA	4	2	6	2	32
JOURNAL OF DAIRY SCIENCE	1.394	USA	1	0	1	3	74
JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY	1.342	USA	15	15	30	4	4
INTERNATIONAL JOURNAL OF FOOD MICROBIOLOGY	1.321	NLD	2	2	4	5	37
ADVANCES IN AGRONOMY	1.308	USA	1	1	2	6	57
JOURNAL OF FOOD PROTECTION	1.292	USA	1	0	1	7	74
SOIL SCIENCE SOCIETY OF AMERICA JOURNAL	1.231	USA	2	1	3	8	47
JOURNAL OF CEREAL SCIENCE	1.221	UKD	2	2	4	9	37
FOOD MICROBIOLOGY	1.193	UKD	0	2	2	10	57

Contribution Rankings

TROPICAL AGRICULTURE	0.098	UKD	19	20	39	90	1
JOURNAL OF THE SCIENCE OF FOOD AND AGRICULTURE	0.866	UKD	20	12	32	24	2
PLANT AND SOIL	0.714	NLD	23	9	32	40	2
JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY	1.342	USA	15	15	30	4	4
CROP SCIENCE	0.648	USA	13	17	30	46	4
FOOD CHEMISTRY	0.683	UKD	17	11	28	42	6
JOURNAL OF AGRICULTURAL SCIENCE	0.621	UKD	16	11	27	48	6
BIOLOGY AND FERTILITY OF SOILS	0.908	USA	11	13	24	20	8
JOURNAL OF AGRONOMY AND CROP SCIENCE-ZEITSCHRIFT FUR ACKER UND PFLANZENBAU	0.192	GER	13	9	22	87	9
THERIOGENOLOGY	1.967	USA	11	6	17	1	10

The shaded journals are the ones occurring in both the rankings.

CLINICAL MEDICINE

JOURNAL TITLE	IF	COUNTRY	1990	1994	TOTAL	RANK/IF	RANK/USE
IF Rankings							
CLINICAL RESEARCH	57.778	USA	2	2	4	1	191
NEW ENGLAND JOURNAL OF MEDICINE	22.673	UKD	6	3	9	2	75
IMMUNOLOGY TODAY	22.047	NLD	1	0	1	3	398
NEURON	18.348		0	2	2	4	311
LANCET	17.332	UKD	31	35	66	5	4
JOURNAL OF EXPERIMENTAL MEDICINE	13.862	USA	1	0	1	6	398
ARCHIVES OF GENERAL PSYCHIATRY	11.416	USA	0	1	1	7	398
ANNALS OF INTERNAL MEDICINE	9.887	USA	3	0	3	8	229
JOURNAL OF THE NATIONAL CANCER INSTITUTE	9.455		1	1	2	9	311
CIRCULATION	8.634	USA	1	1	2	10	311
Contribution Rankings							
INDIAN JOURNAL OF MEDICAL RESEARCH	0.296	IND	96	97	193	539	1
JOURNAL OF NEUROCHEMISTRY	4.525	USA	1	93	94	36	2
INDIAN JRL OF MEDICAL RES SECTION B-BIOMEDICAL RES OTHER THAN INFECTIOUS DISEASES	0.175	IND	73	9	82	557	3
LANCET	17.332	UKD	31	35	66	5	4
EUROPEAN JOURNAL OF PHARMACOLOGY	2.677	NLD	62	2	64	88	5
INTERNATIONAL JOURNAL OF CARDIOLOGY	0.454	NLD	25	32	57	488	6
JOURNAL OF ETHNOPHARMACOLOGY	0.500	IRL	33	16	49	471	7
INTERNATIONAL JOURNAL OF LEPROSY	0.980	USA	25	22	47	332	8
DRUG DEVELOPMENT AND INDUSTRIAL PHARMACY	0.482	USA	14	32	46	481	9
INTERNATIONAL JOURNAL OF DERMATOLOGY	0.578	USA	27	13	40	445	10

The shaded journals are the ones occurring in both the rankings.

BIOMEDICAL RESEARCH

JOURNAL TITLE	IF	COUNTRY	1990	1994	TOTAL	RANK/IF	RANK/USE
IF Rankings							
CELL	39.191	USA	0	1	1	1	219
MOLECULAR AND CELLULAR BIOLOGY	10.195	USA	2	0	2	2	175
DEVELOPMENT	8.064		0	1	1	3	219
JOURNAL OF BIOLOGICAL CHEMISTRY	7.716	USA	8	22	30	4	9
JOURNAL OF VIROLOGY	6.254	USA	2	4	6	5	88
PROGRESS IN BIOPHYSICS & MOLECULAR BIOLOGY	6.115	USA	0	1	1	6	219
JOURNAL OF MOLECULAR BIOLOGY	6.018	UKD	2	11	13	7	38
JOURNAL OF BIOENERGETICS AND BIOMEMBRANES	5.481	USA	1	0	1	8	219
INTERNATIONAL REVIEW OF CYTOLOGY	5.264	USA	1	0	1	9	219
BIOCHEMISTRY	5.234	USA	5	9	14	10	35
Contribution Rankings							
JOURNAL OF BIOSCIENCES	0.432	IND	34	41	75	249	1
BIOCHEMISTRY INTERNATIONAL	0.828	NLD	73	0	73	187	2
BIOCHEMICAL AND BIOPHYSICAL RESEARCH COMMUNICATIONS	3.400	USA	27	28	55	30	3
MEDICAL SCIENCE RESEARCH	0.000		0	52	52	277	4
BIOCHEMISTRY AND MOLECULAR BIOLOGY INTERNATIONAL	0.566	AUS	0	49	49	226	5
MOLECULAR AND CELLULAR BIOCHEMISTRY	1.250	NLD	11	30	41	138	6
FEMS MICROBIOLOGY LETTERS	1.597	NLD	17	21	38	106	7
MUTATION RESEARCH	1.975	NLD	20	17	37	77	8
JOURNAL OF BIOLOGICAL CHEMISTRY	7.716	USA	8	22	30	4	9
ENZYME AND MICROBIAL TECHNOLOGY	1.784	USA	11	14	25	87	10
CURRENT MICROBIOLOGY	0.983	USA	13	12	25	168	10
BIOTECHNOLOGY LETTERS	0.976	UKD	10	15	25	170	10
BIORESOURCE TECHNOLOGY	0.785		0	25	25	195	10
BIOLOGICAL WASTES	0.000	UKD	25	0	25	277	10

The shaded journals are the ones occurring in both the rankings.

ENGINEERING AND TECHNOLOGY

JOURNAL TITLE	IF	COUNTRY	1990	1994	TOTAL	RANK/IF	RANK/USE
IF Rankings							
JOURNAL OF RHEOLOGY	2.315	USA	0	1	1	1	156
ACTA METALLURGICA ET MATERIALIA	2.030		9	9	18	2	25
JOURNAL OF THE MECHANICS AND PHYSICS OF SOLIDS	2.012	USA	0	1	1	3	156
IEEE TRANSACTIONS ON INFORMATION THEORY	1.971	USA	1	0	1	4	156
PROGRESS IN ENERGY AND COMBUSTION SCIENCE	1.833	USA	1	0	1	5	156
IEEE TRANSACTIONS ON ELECTRON DEVICES	1.630	USA	8	10	18	6	25
OXIDATION OF METALS	1.550	USA	1	3	4	7	89
METALLURGICAL TRANSACTIONS A-PHYSICAL METALLURGY AND MATERIALS SCIENCE	1.460	USA	12	2	14	8	37
AICHE JOURNAL-AMERICAN INSTITUTE OF CHEMICAL ENGINEERS	1.359	USA	6	0	6	9	72
AICHE JOURNAL	1.359	USA	0	3	3	9	106
Contribution Rankings							
MICROELECTRONICS AND RELIABILITY	0.152	USA	31	67	98	161	1
SCRIPTA METALLURGICA ET MATERIALIA	0.912		24	31	55	29	2
INDUSTRIAL & ENGINEERING CHEMISTRY RESEARCH	1.056	USA	15	29	44	19	3
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCE	0.633	USA	19	24	43	60	4
JOURNAL OF CHEMICAL AND ENGINEERING DATA	0.930	USA	18	22	40	28	5
JOURNAL OF POWER SOURCES	0.689	SWZ	15	21	36	53	6
CHEMICAL ENGINEERING SCIENCE	0.902	USA	13	19	32	31	7
WEAR	0.580	SWZ	14	18	32	68	7
ELECTRONICS LETTERS	1.159	UKD	18	12	30	16	9
JOURNAL OF CHEMICAL TECHNOLOGY AND BIOTECHNOLOGY	0.581	UKD	13	16	29	67	10

The shaded journals are the ones occurring in both the rankings.

COMPUTERS

JOURNAL TITLE	IF	COUNTRY	1990	1994	TOTAL	RANK/IF	RANK/USE
IF Rankings							
JOURNAL OF COMPUTATIONAL CHEMISTRY	3.769	USA	1	0	1	1	28
JOURNAL OF MOLECULAR GRAPHICS	2.742	USA	0	1	1	2	28
IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE	2.006	USA	0	3	3	3	14
IEEE TRANSACTIONS ON NEURAL NETWORKS	1.941	USA	0	3	3	4	14
NEURAL NETWORKS	1.939	USA	0	1	1	5	28
ARTIFICIAL INTELLIGENCE	1.915	USA	0	2	2	6	19
JOURNAL OF CHEMICAL INFORMATION AND COMPUTER SCIENCES	1.803	USA	1	5	6	7	7
CHEMOMETRICS AND INTELLIGENT LABORATORY SYSTEMS	1.752	NLD	0	1	1	8	28
COMPUTERS & CHEMISTRY	1.380	USA	2	4	6	9	7
IEEE TRANSACTIONS ON SOFTWARE ENGINEERING	1.117	USA	1	0	1	10	28
Contribution Rankings							
COMPUTERS & MATHEMATICS WITH APPLICATIONS	0.304	USA	6	11	17	37	1
IEEE TRANSACTIONS ON SYSTEMS MAN AND CYBERNETICS	0.649	USA	4	12	16	22	2
IEEE TRANSACTIONS ON COMPUTERS	0.904	USA	7	7	14	15	3
PATTERN RECOGNITION	0.691	USA	8	6	14	20	3
INFORMATION SCIENCES	0.266	USA	2	10	12	38	5
INTERNATIONAL JOURNAL OF BIO-MEDICAL COMPUTING	0.576	IRL	1	9	10	26	6
JOURNAL OF CHEMICAL INFORMATION AND COMPUTER SCIENCES	1.803	USA	1	5	6	7	7
COMPUTERS & CHEMISTRY	1.380	USA	2	4	6	9	7
COMPUTER METHODS IN APPLIED MECHANICS AND ENGINEERING	1.018	SWZ	1	3	4	13	9
IEEE TRANSACTIONS ON PARALLEL AND DISTRIBUTED SYSTEMS	0.905	USA	0	4	4	14	9

The shaded journals are the ones occurring in both the rankings.

MATERIAL SCIENCE

JOURNAL TITLE	IF	COUNTRY	1990	1994	TOTAL	RANK/IF	RANK/USE
IF Rankings							
PROGRESS IN MATERIALS SCIENCE	3.385	USA	0	1	1	1	38
CHEMISTRY OF MATERIALS	2.679		1	5	6	2	19
JOURNAL OF BIOMEDICAL MATERIALS RESEARCH	2.104	USA	3	0	3	3	27
DIAMOND AND RELATED MATERIALS	2.017		0	1	1	4	38
JOURNAL OF MATERIALS RESEARCH	2.000	USA	3	20	23	5	9
BIOMATERIALS	1.576	UKD	4	3	7	6	18
JOURNAL OF MATERIALS CHEMISTRY	1.524		0	8	8	7	16
JOURNAL OF THE AMERICAN CERAMIC SOCIETY	1.459	USA	8	8	16	8	11
JOURNAL OF BIOMATERIALS SCIENCE-POLYMER EDITION	1.418		0	2	2	9	33
JOURNAL OF ELECTRONIC MATERIALS	1.238	USA	1	3	4	10	25
Contribution Rankings							
JOURNAL OF MATERIALS SCIENCE LETTERS	0.444		87	87	174	31	1
JOURNAL OF MATERIALS SCIENCE	0.741	UKD	68	55	123	26	2
MATERIALS LETTERS	0.660	NLD	22	24	46	28	3
JOURNAL OF NON-CRYSTALLINE SOLIDS	1.072	NLD	26	15	41	11	4
MATERIALS RESEARCH BULLETIN	0.953	USA	25	15	40	15	5
MATERIALS SCI & ENGG A-STRUC MATERIALS PROPERTIES MICROSTRUCTURE & PROCESSING	0.986	SWZ	16	16	32	14	6
MATERIALS CHEMISTRY AND PHYSICS	0.561	SWZ	8	23	31	30	7
MATERIALS SCIENCE AND ENGINEERING B-SOLID STATE MATERIALS FOR ADVANCED TECHNOLOGY	0.898	SWZ	8	19	27	19	8
JOURNAL OF MATERIALS RESEARCH	2.000	USA	3	20	23	5	9
TEXTILE RESEARCH JOURNAL	0.580	USA	17	0	17	29	10

The shaded journals are the ones occurring in both the rankings.

MULTIDISCIPLINARY

IF Rankings

JOURNAL TITLE	IF	COUNTRY	1990	1994	TOTAL	RANK/IF	RANK/USE
NATURE	25.466	UKD	12	10	22	1	3
NATURE GENETICS	22.568		0	1	1	2	12
SCIENCE	22.067	USA	1	2	3	3	8
SCIENTIFIC AMERICAN	2.881	USA	1	0	1	4	12
NATURWISSENSCHAFTEN	1.163	USA	0	1	1	5	12
SOCIAL STUDIES OF SCIENCE	0.938	UKD	1	0	1	6	12
ANNALS OF THE NEW YORK ACADEMY OF SCIENCES	0.868	USA	4	6	10	7	6
SCIENCE OF THE TOTAL ENVIRONMENT	0.742	NLD	9	4	13	8	4
MEDICAL EDUCATION	0.599	UKD	1	10	11	9	5
SCIENCE PROGRESS	0.514	UKD	2	0	2	10	9

Contribution Rankings

CURRENT SCIENCE	0.271	IND	334	461	795	13	1
JOURNAL OF SCIENTIFIC & INDUSTRIAL RESEARCH	0.237	IND	41	59	100	14	2
NATURE	25.466	UKD	12	10	22	1	3
SCIENCE OF THE TOTAL ENVIRONMENT	0.742	NLD	9	4	13	8	4
MEDICAL EDUCATION	0.599	UKD	1	10	11	9	5
ANNALS OF THE NEW YORK ACADEMY OF SCIENCES	0.868	USA	4	6	10	7	6
PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA	0	USA	4	5	9	18	7
SCIENCE	22.067	USA	1	2	3	3	8
SCIENCE PROGRESS	0.514	UKD	2	0	2	10	9
NEW SCIENTIST	0.328	UKD	1	1	2	12	9
PROCEEDINGS OF THE ROYAL IRISH ACADEMY SECTION B-BIOLOGICAL GEOLOGICAL AND CHEM SCI	0.000	UKD	2	0	2	18	9

The shaded journals are the ones occurring in both the rankings.

5 Scientific Output in the Major Disciplines

The papers in the SCI are not classified by subject field or discipline. However, the Journal Citation Report of ISI does group journals under subject categories. This provides an indication of the discipline of the paper. This classification is not unique and journals may appear under several headings. It is necessary to devise non-overlapping disciplinary categories, even at the cost of some mis-allocation of papers to different categories. It is expected that the volume of data is sufficiently large so that small errors will be statistically averaged out. We have classified the papers into 11 disciplinary areas and a multidisciplinary category.

5.1 Output in the Major Disciplines:

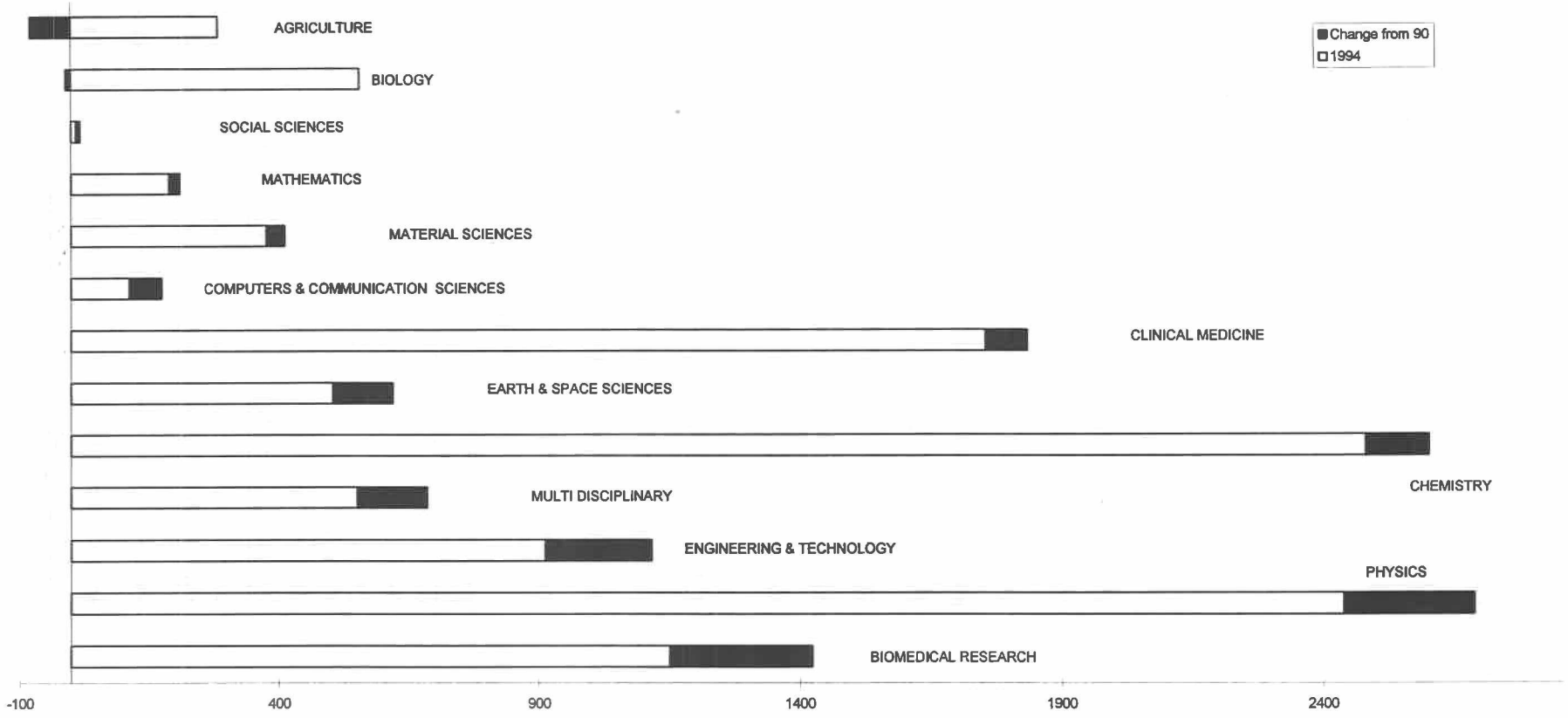
The data shows that the overall number of papers in all disciplines combined has grown from 10103 papers in 1990 to 11314 papers in 1994. The number of papers in each field are shown below in Table 5.1.

Table 5.1. Output in the different Disciplines in Science

Field	*1990*	*1994*	*Field*	*1990*	*1994*
Mathematics	*168*	*189*	Computer Sciences	*51*	*113*
Physics	*2189*	*2438*	Engineering & Tech	*707*	*912*
Chemistry	*2359*	*2480*	Materials Science	*340*	*376*
Biology	*566*	*556*	Earth Sciences	*388*	*504*
Clinical Medicine	*1676*	*1761*	Agriculture	*363*	*284*
Biomedical Research	*879*	*1151*	Multidisciplinary	*417*	*551*
		Total	***10103***	***11314***	

The output in 1994 and change from 1990 to 1994 are shown in Figure 5.1 The ***highest output*** is in the areas of ***Chemistry, Physics*** and ***Clinical Medicine. All the fields have grown from 1990 to 1994 while agriculture has declined.*** The ***highest growth*** has been in the areas of ***Biomedical Research, Physics*** and ***Engineering and Technology***.

Fig 5.1 Number of Indian Papers in Major Diciplines in 1994 & Change from 1990



5.2 Sub-disciplinary areas

In this study, each of the major disciplines has been further broken down into sub-diciplinary areas. Since these sub-disciplinary areas have been constructed by aggregating journals covering a part of a given discipline, the sub-disciplinary categories do not correspond exactly with sub-fields in the classification of the literature. However, we would still expect to obtain an idea of growth or decline in specific areas within a subject field through this process. The disciplines and sub-disciplines that make up our classification scheme are listed in Appendix 3.

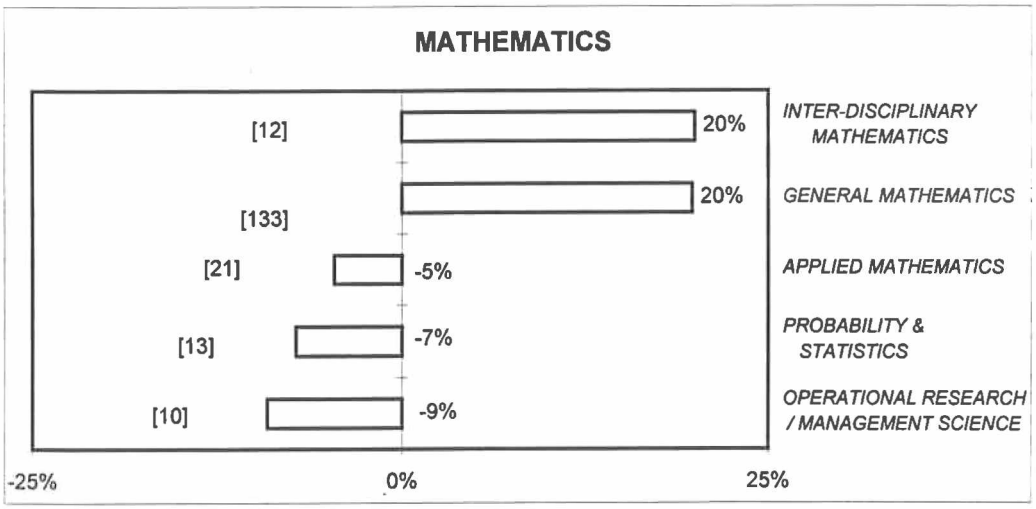
The output in 1994 and percentage change in the sub-disciplinary areas between 1990 and 1994 have been shown in Figure 5.2. The areas with highest output or where major change has taken place between 1990 and 1994 are listed in Table 5.2 below.

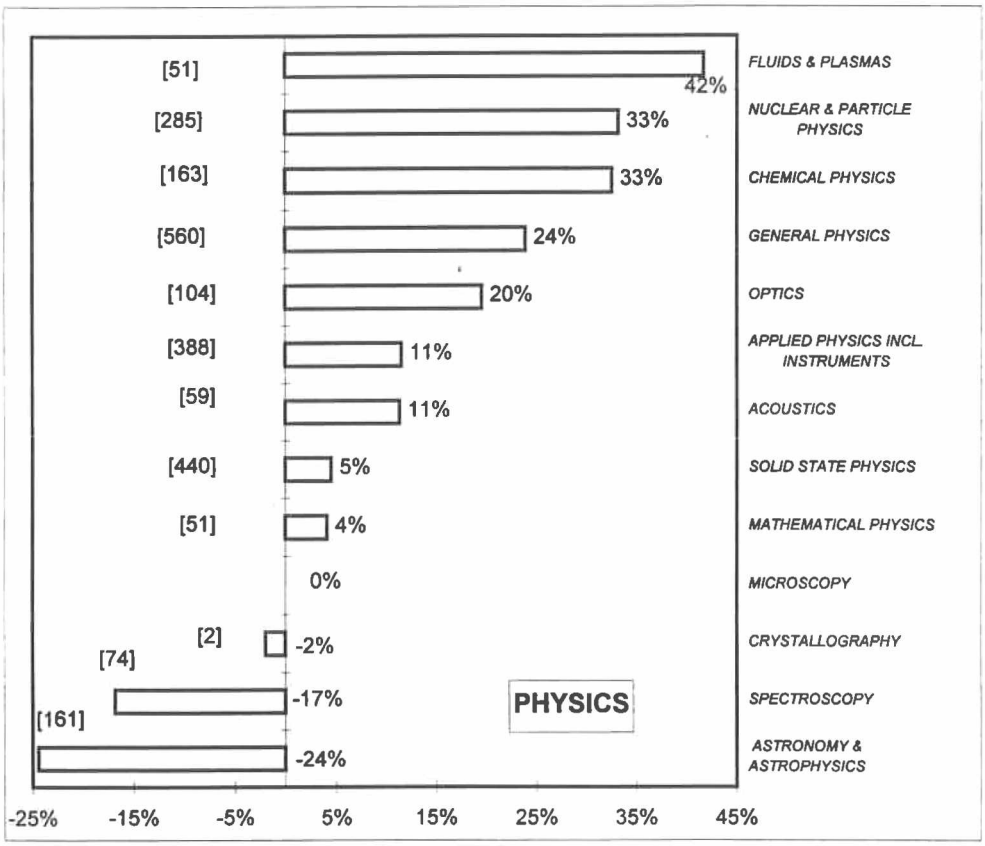
Table 5.2 Output and Change in Sub-disciplinary areas in the Major Disciplines

Highest Output '94	***Highest growth '90 -'94***
General Physics (560) *Biochemistry and Molecular Biology (417)* *Physical Chemistry (372)* *Botany Plant science (332)* *General Materials Science (301)*	*Interdisciplinary Computer Applications (700%)* *Characterization of materials (700%)* *Embryology (400%); Virology (325%)* *Nephrology (325%); Urology (233%)* *Neurology & Neurosurgery (182%)* *Haematology (178%); Addiction (167%);* *Opthalmology (132%)* *Remote Sensing (217%)* *Aerospace Technology (141%)*
Highest Average Impact Factor '94	***Maximum decline '90 - 94***
General & Internal Medicine (22.673) General Biology (15.115) Cancer (9.455)	*Agricultural Economics and Policy (-75%)* *Psychology and Behavioural Science (-75%)* *Software & Graphics (-100%)*

FIG 5.2 PERCENTAGE CHANGE IN PUBLICATION OUTPUT : 1990 - 1994[*]

(Physical Sciences : Sub - fields)

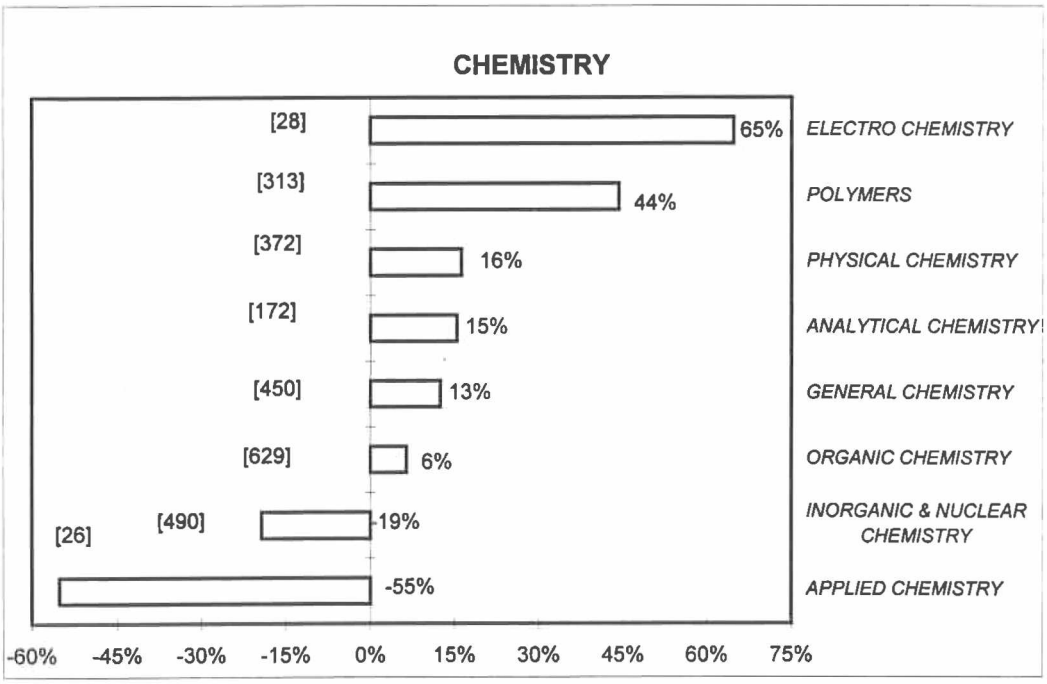


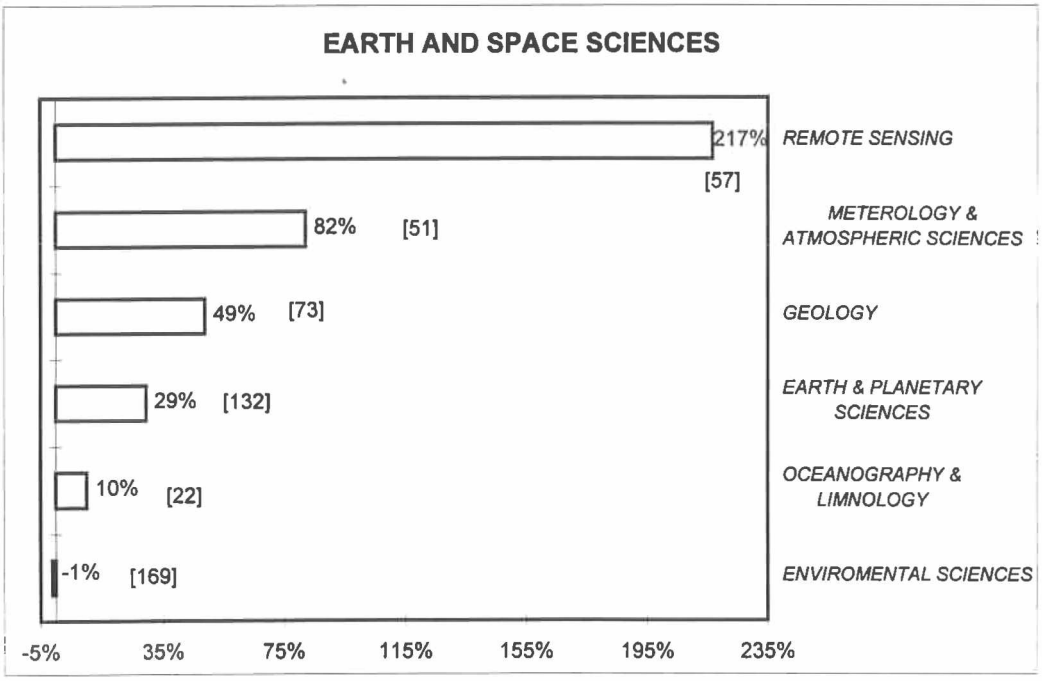


* *Figures in brackets indicate 1994 Scientific Output*

FIG 5.2 PERCENTAGE CHANGE IN PUBLICATION OUTPUT : 1990 - 1994[*] (contd)

(Physical Sciences : Sub - fields)

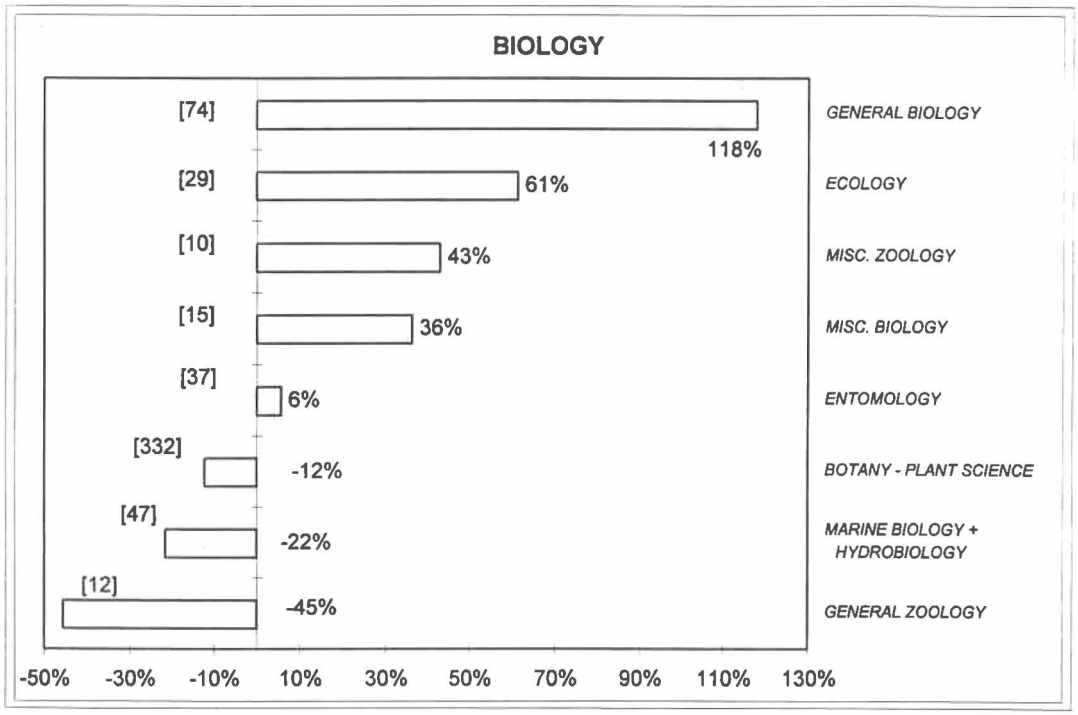


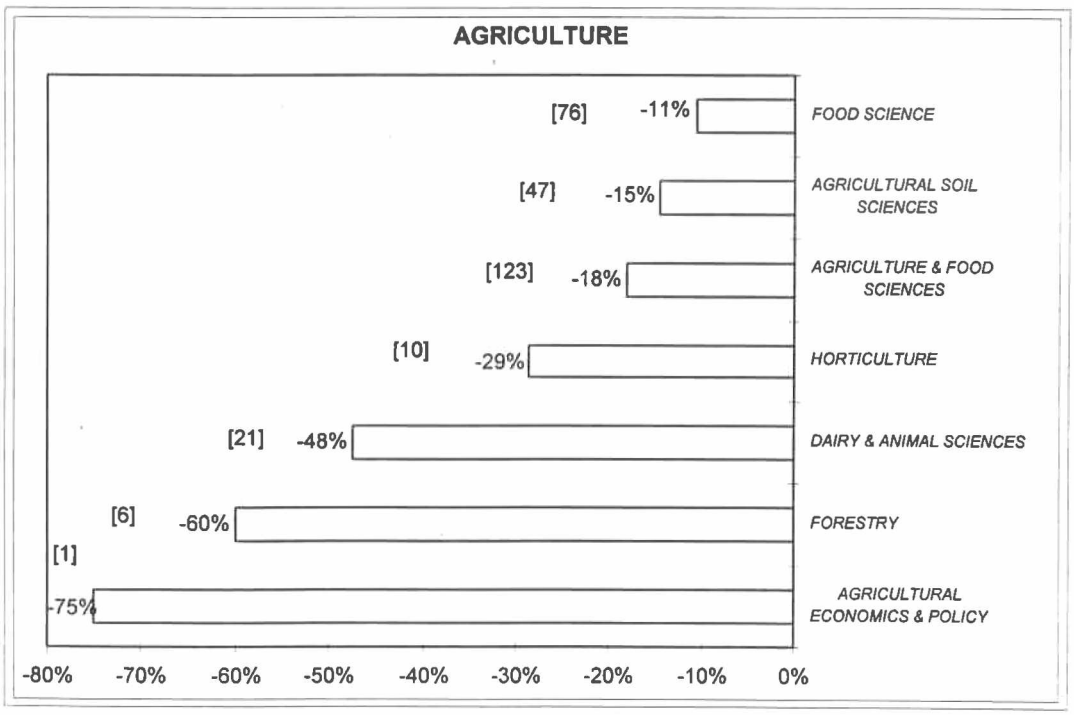


* *Figures in brackets indicate 1994 Scientific Output*

FIG 5.2 PERCENTAGE CHANGE IN PUBLICATION OUTPUT : 1990 - 1994[*] (contd)

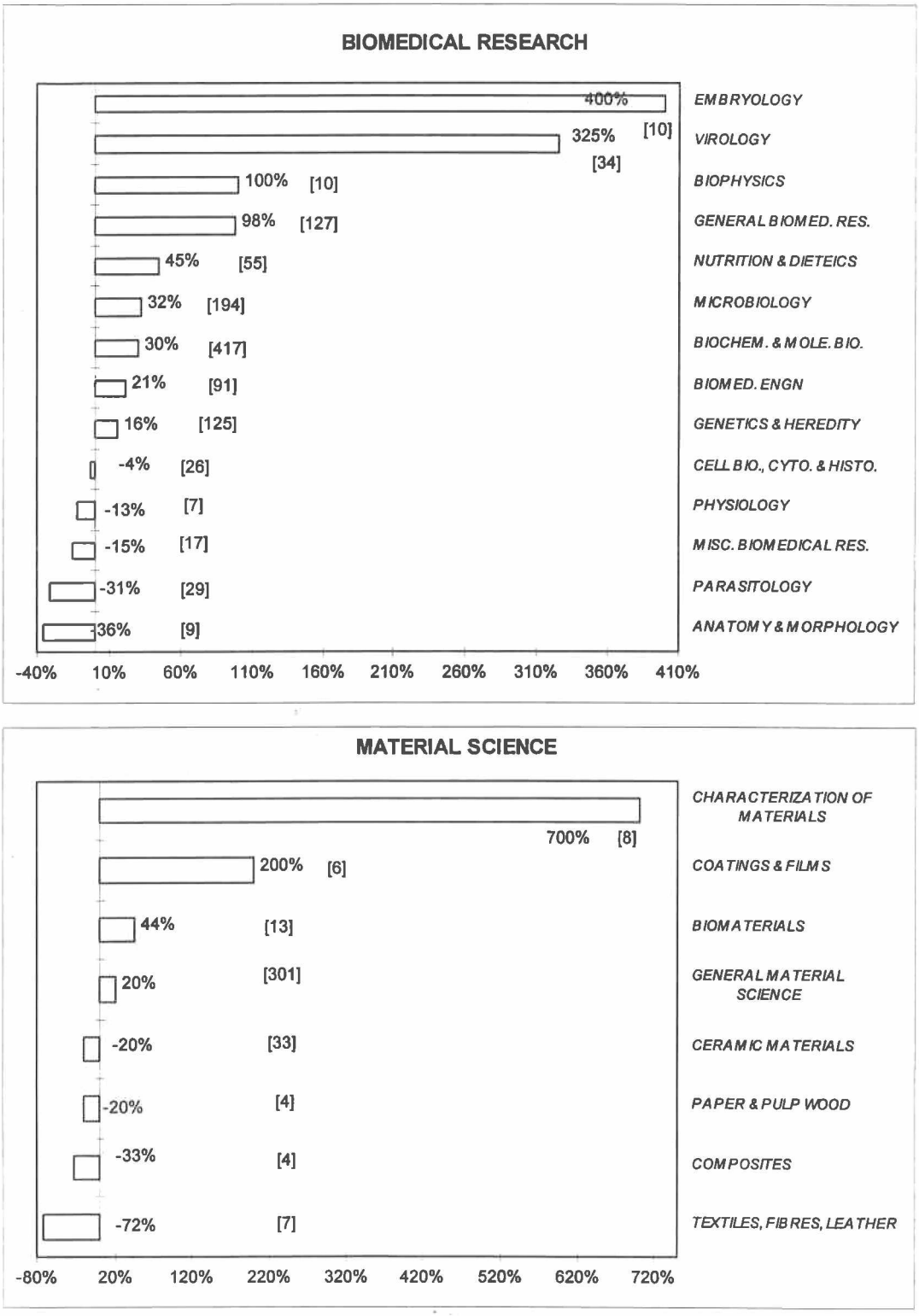
(Bio & Medical Sciences : Sub - fields)





* *Figures in brackets indicate 1994 Scientific Output*

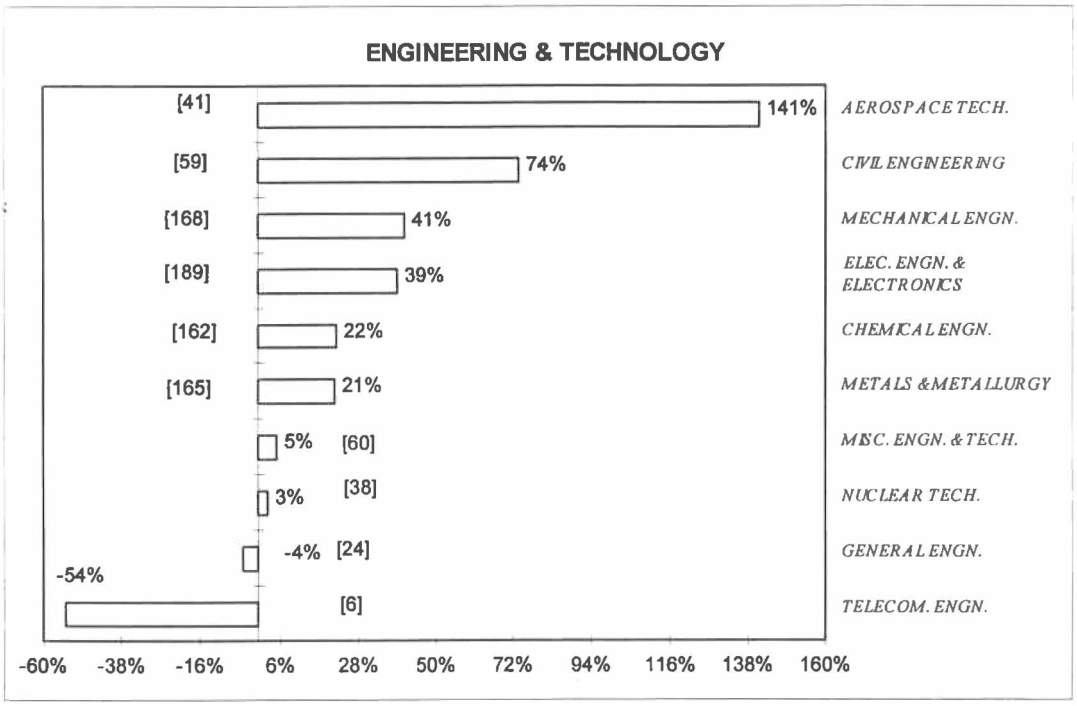
FIG 5.2 PERCENTAGE CHANGE IN PUBLICATION OUTPUT : 1990 - 1994[*] (contd)

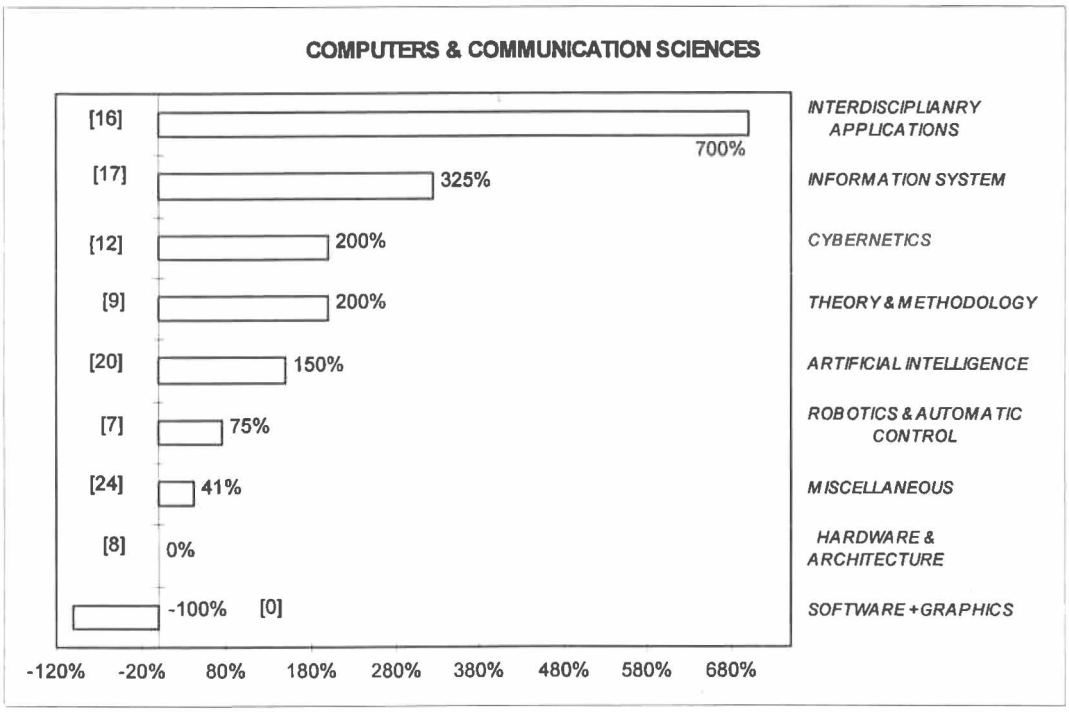


* *Figures in brackets indicate 1994 Scientific Output*

FIG 5.2 PERCENTAGE CHANGE IN PUBLICATION OUTPUT : 1990 - 1994[*] (contd)

(Engineering Sciences : Sub - fields)

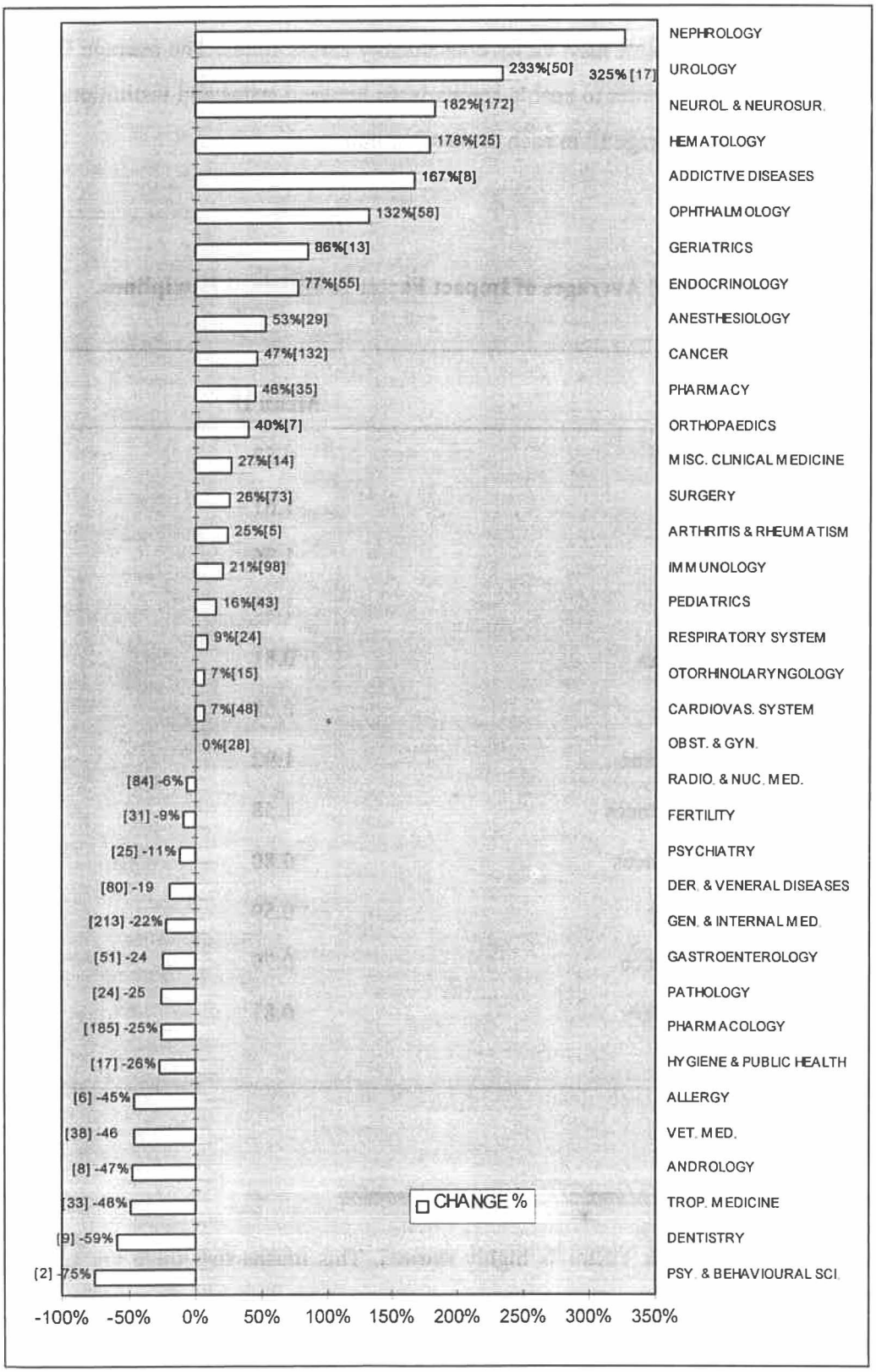




* *Figures in brackets indicate 1994 Scientific Output*

FIG 5.2 PERCENTAGE CHANGE IN PUBLICATION OUTPUT : 1990 - 1994[*] (contd)

(Medical Sciences : Sub - fields)



5.3 Distribution of Impact factor

The Impact Factor of journals used varies considerably across fields. The average IF in each field is computed in order to enable comparisons between states and institutions. In Table 5.3 we show the average IF in each of the disciplines.

Table 5.3. National Averages of Impact Factor in Different Disciplines.

Field	Mean IF
Mathematics	0.52
Physics	1.61
Chemistry	1.26
Biology	1.43
Earth Sciences	0.81
Agriculture	0.68
Clinical Medicine	1.92
Biomedical Sciences	1.58
Computer Sciences	0.80
Engineering	0.59
Materials Science	0.79
Multidisciplinary	0.81

5.3.1 Frequency distribution of Impact Factor in each discipline

The distribution of Impact Factor is highly skewed. This means that there are a few papers with high IF and a large majority of papers with low IF. The frequency distribution of IF for each discipline is shown in Fig 5.3.

FIG 5.3 DISTRIBUTION OF PAPERS IN IMPACT FACTOR RANGE 0-40

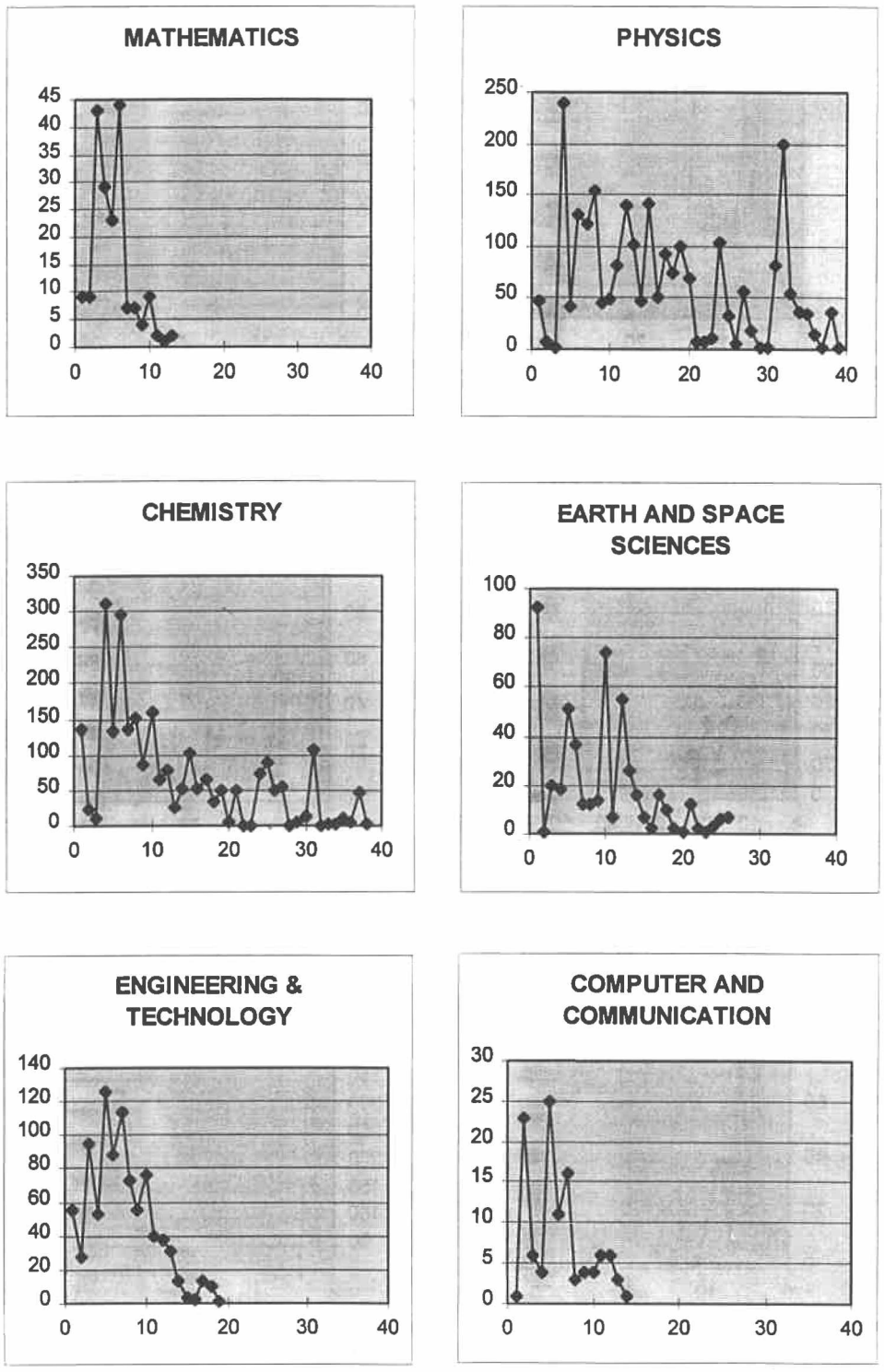
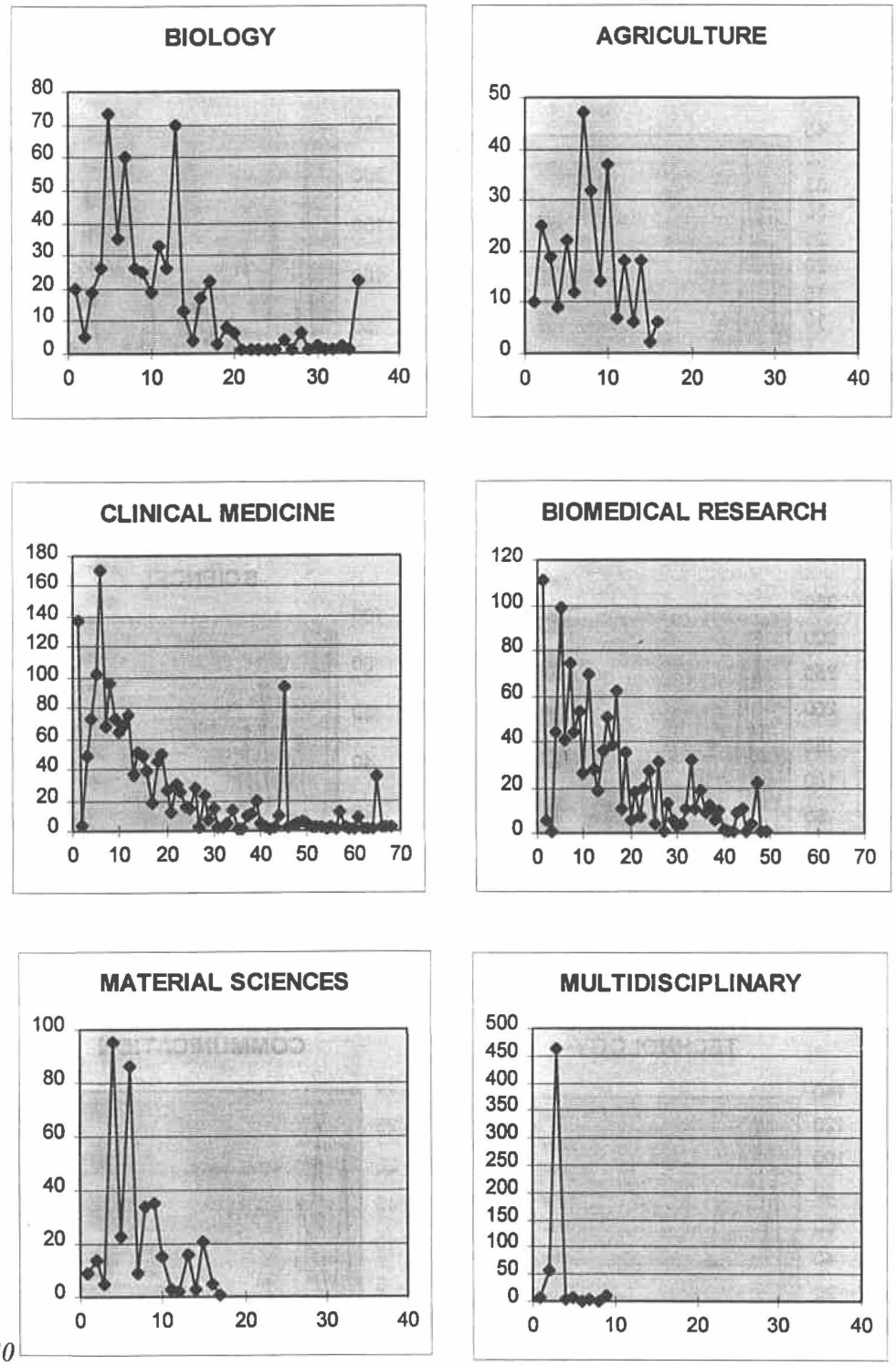


FIG 5.3 DISTRIBUTION OF PAPERS IN IMPACT FACTOR RANGE 0-



40

5.4 Research Profiles of Individual Disciplines

In the following pages we have shown a profile of research output, impact and extent of foreign and interstate collaboration in the different disciplines. In addition we have shown the contributions in sub-disciplinary areas and percentage change between 1990 & 1994. The areas of high output, high growth and decline have also been identified.

Mathematics

	1990	***1994***
No. of Paper	168	189
Rank Among Disciplines	11	11
Average Impact Factor	0.514	0.544
Internationally Co-authored papers	39	47
Interstate Collaborative papers	7	10

Sub-disciplinary Areas	***Papers 94***	***% Change '94-90***
General Mathematics	133	20%
Applied Mathematics	21	-5%
Probability & Statistics	13	-7%
Inter-disciplinary Mathematics	12	20%
Operational Research/Management Science	10	-9%

Areas of High Output	General Mathematics Applied Mathematics
Areas of High Growth	General Mathematics Inter-disciplinary Mathematics
Areas Showing Decline	Operational Research/Management Science Probability & Statistics Applied Mathematics

Physics

	1990	***1994***
No. of Paper	2189	2438
Rank Among Disciplines	2	2
Average Impact Factor	1.466	1.616
Internationally Co-authored papers	309	496
Interstate Collaborative papers	148	232

Sub-disciplinary Areas	***Papers 94***	***% Change '94-90***
General Physics	560	24%
Solid State Physics	440	5%
Applied Physics incl. Instruments	388	11%
Nuclear & Particle Physics	285	33%
Chemical Physics	163	33%
Astronomy & Astrophysics	161	-24%
Optics	104	20%
Crystallography	100	-2%
Spectroscopy	74	-17%
Acoustics	59	11%
Fluids & Plasmas	51	42%
Mathematical Physics	51	4%
Microscopy	2	0%

Areas of High Output	General Physics
	Solid State Physics
	Applied Physcis incl. Instruments
	Nuclear & Particle Physics
Areas of High Growth	Fluids & Plasmas
	Nuclear & Particle Physics
	Chemical Physics
Areas Showing Decline	Astronomy & Astrophysics
	Spectroscopy

Chemistry

	1990	***1994***
No. of Paper	2359	2480
Rank Among Disciplines	1	1
Average Impact Factor	1.089	1.262
Internationally Co-authored papers :	151	207
Interstate Collaborative papers :	63	131

Sub-disciplinary Areas	***Papers 94***	***% Change '94-90***
Organic Chemistry	629	6%
Inorganic & Nuclear Chemistry	490	-19%
General Chemistry	450	13%
Physical Chemistry	372	16%
Polymers	313	44%
Analytical Chemistry	172	15%
Electro Chemistry	28	65%
Applied Chemistry	26	-55%

Areas of High Output	Organic Chemistry Inorganic & Nuclear Chemistry General Chemistry Physical Chemistry Polymers Analytical Chemistry
Areas of High Growth	Electro Chemistry Polymers Physical Chemistry General Chemistry
Areas Showing Decline	Applied Chemistry Inorganic & Nuclear Chemistry

Biology

	1990	***1994***
No of Paper	566	556
Rank Among Disciplines	6	6
Average Impact Factor	0.854	1.488
Internationally Co-authored papers	72	93
Interstate Collaborative papers	23	38

Sub-disciplinary Areas	***Papers 94***	***% Change '94-90***
Botany-Plant Science	332	-12%
General Biology	74	118%
Marine Biology + Hydro-biology	47	-22%
Entomology	37	6%
Ecology	29	61%
Misc. Biology	15	36%
General Zoology	12	-45%
Misc. Zoology	10	43%

Areas of High Output	Botany-Plant Science General Biology Marine Biology + Hydro-biology
Areas of High Growth	General Biology Ecology Misc. Zoology Misc. Biology
Areas Showing Decline :	General Zoology Marine Biology + Hydro-biology Botany-Plant Science

Earth and Space Sciences

	1990	1994
No. of Paper	388	504
Rank Among Disciplines	8	8
Average Impact Factor	0.921	0.89
Internationally Co-authored papers	54	78
Interstate Collaborative papers	38	67

Sub-disciplinary Areas	Papers 94	% Change '94-90
Environmental Sciences	169	-1%
Earth & Planetary Sciences	132	29%
Geology	73	49%
Remote Sensing	57	217%
Meteorology & Atmospheric Sciences	51	82%
Oceanography & Limnology	22	10%

Areas of High Output

- Environmental Sciences
- Earth & Planetary Sciences
- Geology
- Remote Sensing
- Meteorology & Atmospheric Sciences

Areas of High Growth

- Remote Sensing
- Meteorology & Atmospheric Sciences
- Earth & Planetary Sciences

Areas Showing Decline

Agriculture

	1990	***1994***
No. of Paper	363	284
Rank Among Disciplines	9	10
Average Impact Factor	0.721	0.686
Internationally Co-authored papers	41	43
Interstate Collaborative papers	18	12

Sub-disciplinary Areas	***Papers 90***	***Papers 94***	***% Change '94-90***
Agriculture & Food Sciences		129	-18%
Food Science		76	-11%
Agricultural Soil Sciences		47	-15%
Dairy & Animal Sciences		21	-48%
Horticulture		10	-29%
Forestry		6	-60%
Agricultural Economics & Policy		1	-75%

Areas of High Output

Agriculture & Food Sciences
Food Science
Agricultural Soil Sciences
Dairy & Animal Sciences

Areas of High Growth

Areas Showing Decline :

Agricultural Economics & Policy
Dairy & Animal Sciences
Agriculture & Food Sciences
Agricultural Soil Sciences

Clinical Medicine

	1990	1994
No. of Paper	1676	1761
Rank Among Disciplines	3	3
Average Impact Factor	1.709	1.962
Internationally Co-authored papers	131	223
Interstate Collaborative papers	67	94

Sub-disciplinary Areas	*Papers 94*	*% Change '94-90*
Gastroenterology	213	-22%
Hygiene & Public Health	185	-25%
Neurology I & Neurosurgery	172	182%
Cancer	132	47%
Immunology	98	21%
Radio. & Nuclear. Clinical Medicine.	84	-6%
Gen. & Internal Clinical Medicine.	80	-19%
Surgery	73	26%
Ophthalmology	58	132%
Endocrinology	56	77%
Pathology	51	-24%
Urology	50	233%
Cardiovascular. System	48	7%
Paediatrics	43	16%
Andrology	38	-46%
Pharmacy	36	46%
Dentistry	33	-48%
Fertility	31	-9%
Anaesthesiology	29	53%
Dermatology. & Venereal Diseases	27	-11%
Haematology	25	178%
Respiratory System	24	9%
Pharmacology	24	-25%
Nephrology	17	325%
Allergy	17	-26%
Otorhinolaryngology	15	7%
Misc. Clinical Medicine	14	27%
Geriatrics	13	86%
Psychology & Behavioural Sciences	9	-59%
Addictive Diseases	8	167%
Trop. Medicine	8	-47%
Orthopaedics	7	40%
Vet. Clinical Medicine.	6	-45%
Arthritis & Rheumatism	5	25%
Obstretics . & Gynaecology	2	0%

Areas of High Output	Areas of High Growth	Areas Showing Decline
Gastroenterology	Nephrology	Obstretics & Gynaecology
Hygiene & Public Health	Urology	Psy. & Behavioural Sci.
Neurology & Neurosurgery	Neurology & Neurosurgery	Dentistry
Cancer		

Biomedical Research

	1990	***1994***
No. of Paper	879	1150
Rank Among Disciplines	4	4
Average Impact Factor	1.449	1.63
Internationally Co-authored papers	91	173
Interstate Collaborative papers	27	68

Sub-disciplinary Areas	***Papers 94***	***% Change '94-90***
Biochem. & Molecular . Bio.	417	30%
Microbiology	194	32%
General Biomed. Research .	127	98%
Genetics & Heredity	125	16%
Biomed. Engineering	91	21%
Nutrition & Dietetics	55	45%
Virology	34	325%
Parasitology	29	-31%
Cell Biology., Cytology. & Histology	26	-4%
Misc. Biomedcial Research.	17	-15%
Embryology	10	400%
Biophysics	10	100%
Anatomy & Morphology	9	-36%
Physiology	7	-13%

Areas of High Output	Biochem. & Molecular Biology
	Microbiology
	General Biomed. Research
Areas of High Growth	Embryology
	Virology
	Biophysics
	General Biomed. Research
Areas Showing Decline	Anatomy & Morphology
	Parasitology
	Misc. Biomedcial Research

Engineering & Technology

	1990	***1994***
No. of Paper :	707	912
Rank Among Disciplines :	5	5
Average Impact Factor :	0.623	0.598
Internationally Co-authored papers :	74	91
Interstate Collaborative papers :	59	92

Sub-disciplinary Areas	***Papers 94***	***% Change '94-90***
Electrical. Engineering. & Electronics	189	39%
Mechanical Engineering.	168	41%
Metals & Metallurgy	165	21%
Chemical Engineering.	162	22%
Misc. Engineering. & Tech	60	5%
Civil Engineering	59	74%
Aerospace Technology	41	141%
Nuclear Technology.	38	3%
General Engineering.	24	-4%
Telecommunication. Engineering.	6	-54%

Areas of High Output	Elec. Engineering. & Electronics Mechanical Engineering. Metals & Metallurgy Chemical Engineering.
Areas of High Growth	Aerospace Technology Civil Engineering Mechanical Engineering.
Areas Showing Decline	Telecommunication. Engineering. General Engineering.

Computer & Communication Sciences

	1990	***1994***
No. of Paper	51	113
Rank Among Disciplines	12	12
Average Impact Factor	0.727	0.819
Internationally Co-authored papers	14	25
Interstate Collaborative papers	3	6

Sub-disciplinary Areas	***Papers 94***	***% Change '94-90***
Miscellaneous	24	41%
Artificial Intelligence	20	150%
Information System	17	325%
Interdisciplinary Applications	16	700%
Cybernetics	12	200%
Theory & Methodology	9	200%
Hardware & Architecture	8	0%
Robotics & Automatic Control	7	75%
Software + Graphics	0	-100%

Areas of High Output	Miscellaneous Artificial Intelligence Information System
Areas of High Growth	Interdisciplinary Applications Information System Cybernetics
Areas Showing Decline	Software + Graphics

Material Science

	1990	*1994*
No. of Paper	340	376
Rank Among Disciplines	10	9
Average Impact Factor	0.734	0.802
Internationally Co-authored papers	30	37
Interstate Collaborative papers	17	31

Sub-disciplinary Areas	*Papers 94*	*% Change '94-90*
General Material Science	301	20%
Ceramic Materials	33	-20%
Bio-materials	13	44%
Characterisation of Materials	8	700%
Textiles, Fibres, Leather	7	-72%
Coatings & Films	6	200%
Paper & Pulp Wood	4	-20%
Composites	4	-33%

Areas of High Output	General Material Science Ceramic Materials Bio-materials
Areas of High Growth	Characterisation of Materials Coatings & Films Bio-materials
Areas Showing Decline	Textiles, Fibres, Leather Composites Paper & Pulp Wood

Multidisciplinary

	1990	***1994***
No. of Paper	417	551
Rank Among Disciplines	7	7
Average Impact Factor	1.179	0.95
Internationally Co-authored papers	19	32
Interstate Collaborative papers	11	30

6 Sectoral Output in the basic Scientific disciplines

In this chapter we examine the output of scientific publications from the different sectors in the SCI. The broad sectors are,

6.1 Major Sectors

1. Central Government Sector

- *Major Scientific Agencies*
- *Other Agencies of Ministries and Departments*

2. State government Sector

3. Academic Sector

- *Universities*
- *Other academic institutions (deemed universities, IIT's, institutes of advanced study, colleges, schools etc.).*

4. Industrial Sector.

- *Private and Public Sector*

5. Health Sector

- *Hospitals & Medical colleges*

The relative output of the sectors is shown in Fig.6.1. After assigning the output to the respective sectors there remained about 3% addresses that could not be assigned. In addition there were about 0.2% papers with only residential addresses.

A list of the major Agencies and other ministries and departments of the Governmcnt of India is shown in Table 6.1

Table 6.1. **Major Scientific Agencies and Other Ministries and Departments of the Government**

1	DAE	Department of Atomic Energy	24	MHFW	Ministry of Health and Family Welfare
2	CSIR	Council of Scientific and Industrial Research	25	MHA	Ministry of Home Affairs
3	DRDO	Defence Research Development Organisation	26	DOCu	Department of Culture
4	DOE	Department of Electronics	27	DHI	Department of Heavy Industry
5	MOEn	Ministry of Environment and Forests	28	DID	Department of Industrial Development
6	ICAR	Indian Council of Agricultural Research	29	DSSI	Department of Small Scale Industries, Agro and Rural Industries
7	ICMR	Indian Council of Medical Research	30	MI&B	Ministry of Information and Broadcasting
8	DBT	Department of Biology-Technology	31	MOL	Ministry of Labour
9	DSIR	Department of Scientific and Industrial Research	32	MOM	Ministry of Mines
10	DOS	Department of Space	33	MPNG	Ministry of Petroleum and Natural Gas
11	DA&C	Department of Agriculture and Cooperation	34	DOSt	Department of Statistics
12	DAHD	Department of Animal Husbandary and Dairying	35	MOP	Ministry of Power
13	DCP	Department of Chemicals and Petrochemicals	36	MOR	Ministry of Railways
14	DOF	Department of Fertilizers	37	MRD	Ministry of Rural Development
15	DCA	Department of Civil Aviation	38	MOSI	Ministry of Steel
16	MCS	Department of Civil Supplies	39	MSTt	Ministry of Surface Transport
17	MOC	Ministry of Coal	40	MUD	Ministry of Urban Development
18	MOCo	Ministry of Commerce	41	MOW	Ministry of Welfare
19	DOT	Department of Telecommunications	42	MOTx	Ministry of Textiles
20	DODe	Depatment of Defence	43	MWR	Ministry of Water Resources
21	DDPS	Department of Defence Production and Supplies	44	MHRD	Ministry of Human Resources Development
22	MOFo	Ministry of Food	45	MNCER	Ministry of Non Conventional Energy Resources
23	MFPI	Ministry of Food Processing Industries	46	DOM	Department of Meteorology

6.1.1 Sectoral Output

The output of the sectors for the years 1994 and 1990 has been tabulated (Table 6.2a, b) and their relative proportions indicated in Figure 6.1.

An analysis of the data shows that the ***Academic sector*** is by far the largest sector in terms of scientific publications, accounting for almost ***half*** of the total output.

This is followed by the Government Sector, ***Major Scientific Agencies*** and ***other agencies*** accounting for ***one -third*** of the output.

Institutions associated with the ***Ministries and Departments*** of the Government of India, other than the major agencies, amounted to ***5.6 percent.***

The ***Health Sector*** accounted for ***4.5 percent*** of the total output.

The ***Industrial sector*** accounted for ***2.8 percent,***

The ***State Government Sector*** accounted for ***0.7 percent,***

Private addresses accounted for ***0.1 percent*** , while ***3 percent*** of the papers could not be identified with any of the sectors.

Table 6.1b summarises the output percentages for the sectors for both the years.

Table 6.1b. Scientific publication output of the major sectors in India (SCI data)

Sector	1990	1994
Academic sector	54%	49.8%
Government Agencies	35%	39%
Industrial Sector	2%	3%
Hospital and Medical Colleges	5%	5%
Unidentified	3%	3%

Though there is a increase in the overall contributions the contribution percentages of the Major sectors have very little changes. Scientific Agencies and Universities are the only sectors which have shown any substantial change. The industrial sector has marginal growth All the remaining sectors have maintained there contributions. There is very little change in the overall picture between 1990 and 1994.

Fig 6.1a Percentage Contributions of Major Sectors 1990

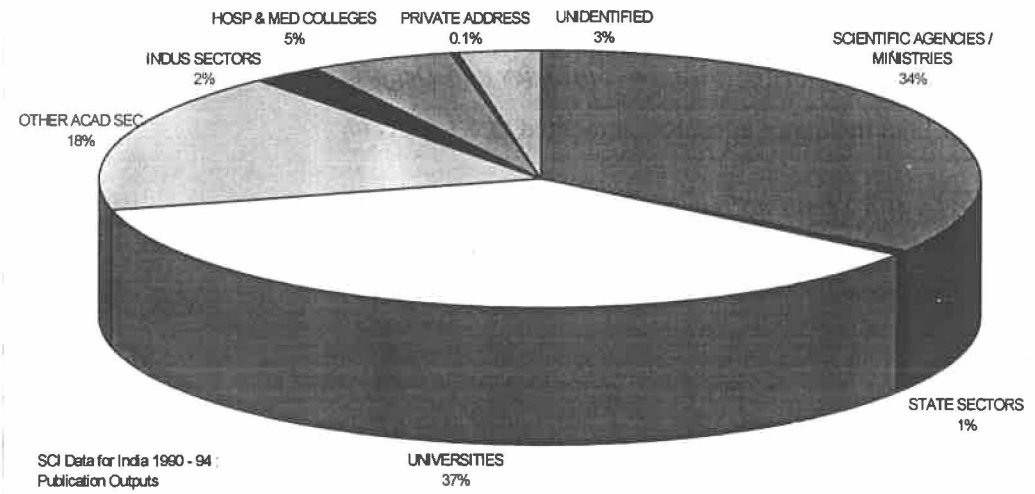
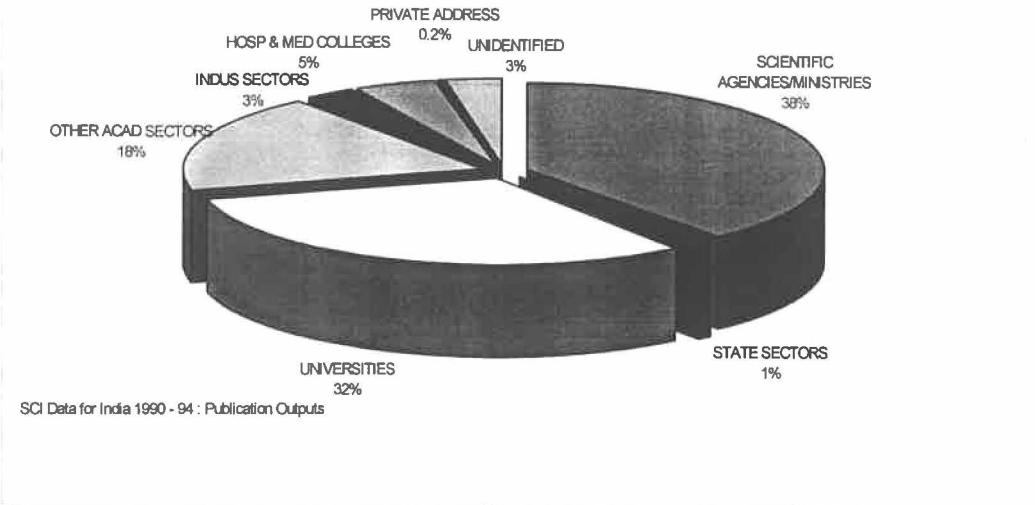


Fig 6.1b Percentage Contributions of Major Sectors 1994



* *SCI Data for India 1990 - 94 : Publication Output*

Table 6.2a SECTORAL OUTPUT OF SCIENTIFIC PAPERS BY DISCIPLINES : SCI Data 1994

SECTORS	MAT	PHY	CHE	BIO	GEO	AGRI	MED	BMD	ENGG	COMP	MTL	MUL	TOTAL	%	AVG IF
MAJOR SCIENTIFIC AGENCIES															
DAE	30	623	183	18	16	8	88	59	80	2	32	31	1170	8.82%	1.733
CSIR	3	161	488	68	102	41	101	207	99	5	83	93	1451	10.94%	1.325
DRDO		37	16	1	7	2	18	7	32		14	6	140	1.06%	0.913
DOE		2			1				7	1		2	13	0.10%	0.543
MOEn		2		16	8		2					2	30	0.23%	0.562
ICAR			8	44	7	43	11	33	3			16	165	1.24%	0.733
ICMR			2	9	2	4	101	44		1		7	170	1.28%	1.649
DBT				4		4	27	21				3	59	0.44%	2.929
DST		231	107	13	43		21	44	6		23	65	553	4.17%	1.446
DOS		61	7		72				27		3	13	183	1.38%	1.187
MHFW		2	6	7	1	1	392	76		3		5	493	3.72%	2.034
OTHER MINISTRIES/DEPARTMENTS	31	31	53	16	34	10	411	85	24	21	4	26	746	5.62%	1.663
STATE SECTORS	0	7	3	3	10	2	58	6	0	0	1	1	91	0.69%	1.259
UNIVERSITIES	79	999	1144	307	160	132	320	469	265	25	110	178	4188	31.57%	1.103
OTHER ACADEMIC SECTORS	51	611	610	53	93	22	46	164	452	67	134	105	2408	18.15%	1.274
PRIVATE SECTORS	6	9	51	8	3	1	196	44	25	2	6	18	369	2.78%	1.531
HOSPITALS & MEDICAL COLLEGES		6	11	4			500	69	2			10	602	4.54%	1.835
PRIVATE ADDRESS		1		3	3		4		1			11	23	0.17%	2.859
UNIDENTIFIED	10	77	44	46	23	40	68	35	29	4	10	27	413	3.11%	1.309
TOTAL	*210*	*2860*	*2733*	*620*	*585*	*310*	*2364*	*1363*	*1052*	*131*	*420*	*619*	*13267*	100%	1.358

Table 6.2b : Sectoral Ouput Of Scientific Papers by Disciplines : SCI 1990

SECTOR	MATHS	PHYS	CHEM	BIO	GEO	AGRI	MED	BMD	ENGG	COM	MTL	MUL	TOTAL	%	AVG_IF
MAJOR SCIENTIFIC AGENCIES															
DAE	41	447	161	14	6	12	78	66	52	5	14	22	918	8.25%	1.557
CSIR	4	122	383	62	108	33	129	148	103	2	65	74	1233	11.08%	1.271
DRDO		22	14	3	3	3	20	2	31		16	5	119	1.07%	0.867
DOE		1					1		1	1			4	0.04%	0.361
MOEn				11	3	3	2					1	20	0.18%	0.620
ICAR		1	9	43	9	75	15	26	6		1	22	207	1.86%	0.722
ICMR			2	4	2	1	109	25				6	149	1.34%	2.274
DBT							18	4				1	23	0.21%	2.255
DST		182	89	12	24		20	34	5		16	31	413	3.71%	1.545
DOS	2	38	9	1	33			3	11	1	2	6	106	0.95%	1.526
MHFW		3	4	3	1	2	393	49		1	1	3	460	4.14%	1.623
OTHER MINISTRIES / DEPARTMENTS	28	29	28	9	12	6	6	14	12	5	15	15	179	1.61%	0.994
STATE SECTORS	0	3	4	2	4	8	44	4	0	0	2	2	73	0.66%	1.050
UNIVERSITIES	60	930	1141	347	151	175	326	390	218	6	110	153	4007	36.02%	1.000
OTHER ACADEMIC SECTORS	41	589	528	33	71	20	51	115	309	32	119	71	1979	17.79%	1.135
PRIVATE SECTORS	2	23	44	7	6	3	143	21	17	1	5	5	277	2.49%	1.647
HOSPITALS & MEDICAL COLLEGES		9	16	8	1		500	51	1	1		9	596	5.36%	1.750
PRIVATE ADDRESS		1			2	2	1		4			1	11	0.10%	0.779
UNIDENTIFIED	4	47	72	41	11	44	56	17	26	2	15	15	350	3.15%	1.522
TOTAL	182	2447	2504	600	447	387	1912	969	796	57	381	442	11124	100.00%	1.236

6.1.2 Change in Sectoral Output (1990-1994)

It is seen that though there has been an overall increase in the number of publications the relative proportion of the contribution of the major sectors has not changed substantially in the period 1990-1994 (Figure 6.1a,b). The overall output of the scientific agencies has improved by a few percentage points. Incidentally it may be pointed out that not all the research work within an organisation need be published in the form of journal articles, an example being DRDO, much of whose research may be classifed.

The ***Major Scientific Agencies*** have increased their output by 3.4 percentage points, and other ministries by 4 percentage points.

The ***Academic sector*** has declined by 4 percentage points.

The ***Health sector*** has increased its scientific publications by 0.9 percentage points.

The ***Industrial sector*** contributed 0.3 percent more papers in 1994.

Publications from ***private addresses*** doubled to 0.2 percent of the total in 1994.

6.1.3 Impact Factor

In comparing the impact factor of different sectors, it should be kept in mind that many sectors publish in just a few disciplines while others publish in a variety of disciplines. There are significant differences in the citation patterns and impact factors of journals in different disciplines. Therefore comparisons of impact may not always be justified. The average Impact Factors for all the sectors have been tabulated in Table (6.3a,b)

Table 6.3a : AVERAGE IMPACT FACTOR OF SECTORAL OUPUT BY DISCIPLINE : SCI Data 1994 for India

SECTORS	MATHS	PHYS	CHEM	BIO	EARTH	AGRI	MEDICINE	BIOMED	ENGG	COMP.	MATER.	MULTI	TOTAL
MAJOR SCIENTIFIC AGENCIES													
DAE	0.526	2.015	1.229	1.199	0.919	0.754	2.357	2.936	0.676	0.994	0.599	1.086	1.733
CSIR	0.129	1.515	1.475	1.466	0.889	0.847	2.045	1.775	0.620	1.267	0.798	0.278	1.325
DRDO		1.299	0.866	1.257	0.657	0.429	0.894	0.953	0.672		0.956	0.260	0.913
DOE		0.795			0.892				0.487	0.629		0.271	0.543
MOEn		1.307		0.556	0.496		0.418					0.271	0.562
ICAR			0.901	0.725	1.059	0.664	0.955	0.898	0.486			0.267	0.733
ICMR			0.783	0.775	0.000	0.953	1.571	1.297		0.400		7.392	1.649
DBT				8.056		1.689	2.489	3.150				0.169	2.929
DST		1.858	1.629	1.004	0.805		0.838	1.903	0.611		1.130	0.271	1.446
DOS		1.859	0.840		1.119				0.443		0.615	0.271	1.187
MHFW		0.308	0.510	8.983	0.250	1.103	1.995	1.299		0.887		10.295	2.034
OTHER MINISTRIES/DEPTS	0.621	1.085	1.620	4.315	0.717	0.892	1.950	1.285	0.591	0.766	0.351	2.196	1.663
STATE SECTORS		1.052	0.598	1.308	1.179	0.436	1.425	0.919			0.357	0.271	1.259
UNIVERSITIES	0.487	1.348	0.966	1.500	0.669	0.618	1.763	1.291	0.581	0.851	0.740	0.289	1.103
OTHER ACADEMIC SECTORS	0.534	1.670	1.600	0.953	0.658	0.654	1.560	1.801	0.595	0.759	0.817	1.166	1.274
PRIVATE SECTORS	0.423	0.892	1.168	2.701	0.520	0.648	1.961	1.401	0.552	0.714	0.751	0.287	1.531
HOSPITALS & MEDICAL COLLEGES		1.705	0.376	5.026			1.884	1.114	0.739			4.993	1.835
PRIVATE ADDRESS		0.308		0.400	1.022		1.846		0.427			4.852	2.859
UNIDENTIFIED	0.752	1.381	1.054	1.017	0.668	0.669	2.876	1.947	0.447	0.589	0.544	0.256	1.309
TOTAL	0.529	1.618	1.255	1.535	0.790	0.693	1.910	1.544	0.592	0.794	0.784	0.869	1.358

Table 6.3b : AVERAGE IMPACT FACTOR OF SECTORAL OUPUT BY DISCIPLINE : SCI Data 1990 for India

SECTORS	MAT	PHY	CHE	BIO	GEO	AGRI	MED	BMD	ENG	COMP	MTL	MUL	TOTAL
MAJOR SCIENTIFIC AGENCIES													
DAE	0.385	2.808	1.397	1.541	2.451	0.502	2.659	2.624	1.040	0.398	1.369	1.530	2.209
CSIR	0.097	1.999	1.879	1.607	0.840	1.052	1.601	2.482	0.596	3.167	1.019	0.349	1.559
DRDO		2.185	0.990	0.419	1.533	0.286	0.804	3.335	0.694		0.837	0.312	1.074
DOE		1.589					0.000		3.410	0.629			1.766
MOEn				0.809	1.323	0.000	0.418					0.542	0.843
ICAR		0.000	0.801	0.742	0.824	0.381	0.700	1.140	0.243		0.000	0.194	0.584
ICMR			0.783	1.744	0.000	3.811	1.456	2.283				8.624	1.881
DBT							3.734	16.536				0.508	7.514
DST		2.358	1.959	1.088	1.442		0.879	2.463	0.733		1.624	0.568	1.937
DOS	0.000	2.983	0.653	0.000	2.441			0.000	1.089	0.000	0.923	0.587	2.048
MHFW		0.205	0.765	20.959	0.250	0.552	1.990	2.014		2.661	0.000	17.158	2.180
OTHER MINISTRIES/DEPARTMENTS	0.687	1.160	3.066	7.672	2.031	1.487	133.592	7.804	1.182	3.219	0.094	3.806	6.931
STATE SECTORS		2.455	0.449	1.963	2.947	0.109	1.878	1.378			0.179	0.136	1.569
UNIVERSITIES	0.641	1.449	0.969	1.327	0.709	0.466	1.730	1.553	0.706	3.544	0.740	0.337	1.152
OTHER ACADEMIC SECTORS	0.664	1.733	1.849	1.531	0.862	0.719	1.407	2.569	0.870	1.588	0.919	1.724	1.551
PRIVATE SECTORS	1.270	0.349	1.354	3.087	0.260	0.216	2.688	2.936	0.812	1.427	0.901	1.034	2.040
HOSPITALS & MEDICAL COLLEGES		1.136	0.259	2.513	0.000		1.884	1.507	1.477	0.000		5.548	1.854
PRIVATE ADDRESS		0.308			1.534	0.000	7.383		0.107			53.371	5.978
UNIDENTIFIED	1.880	2.263	0.644	1.141	1.396	0.608	3.493	4.009	0.498	1.179	0.362	0.461	1.544
TOTAL	0.611	1.891	1.370	1.587	1.034	0.555	2.362	2.172	0.783	1.824	0.864	1.217	1.619

6.2 The Major Scientific Agencies

The major scientific agencies are administered using government funds and have affiliated institutions and laboratories. Unlike the university sector there is less or none of the teaching function. A list of major scientific agencies and departments has been shown in Table 6.1

The distribution of the scientific output of the major scientific agencies and other ministries is shown in Figure 6.2. Among the Major Scientific Agencies, the largest output is from the ***Council of Scientific & Industrial Research*** (CSIR) whose output declined slightly from 11.1% in 1990 to 10.9% in 1994, followed by ***Department of Atomic Energy*** (DAE including affiliated institutions) whose output increased form 8.3% to 8.8%. The ***Department of Science & Technology*** (DST, and affiliated institutions) accounted for 4.2% of the total in 1994, an increase of 0.5 percentage points. The output of the ***Indian Council of Agricultural Research*** (ICAR), fell by 0.7% from 1.9% to 1.2%.

The average impact factors are highest for publications from the ***Department of Biotechnology*** (2.93) and ***Ministry of Health and Family Welfare*** (2.03). For ***Hospitals and medical colleges*** the IF is 1.84 while for the ***Indian Council of Medical Research*** (ICMR) it is 1.65. These figures, however, may reflect the higher impact of journals in the Medical and Biological Sciences.

The ***Department of Atomic Energy*** has a high impact (1.73), as also the ***Department of Science & Technology*** (1.65).

CSIR and DAE are the top contributors for both the years and have both registered an increase from 90 to 94. While most of the agencies have either maintained or increased their contributions the Ministry of Health & Familty Welfare, ICAR and ICMR have shown a decline. The decline in contributions from these agencies are made up by other Ministries and departments which have registered an increase of around 180 % from 90 to 94.

Fig 6.2a Percentage Contributions Among Major Scientific Agencies 1990

Fig 6.2a Percentage Contribution Among Major Scientific Agencies 1990

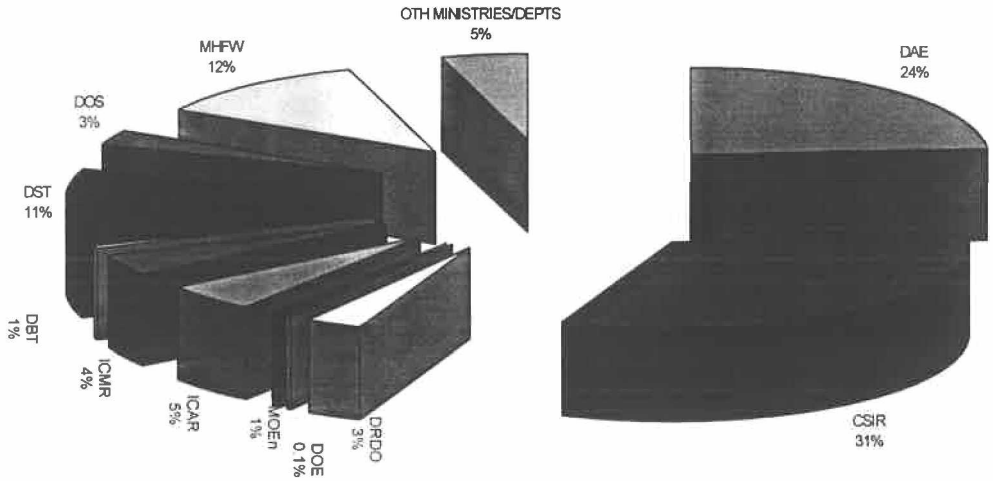
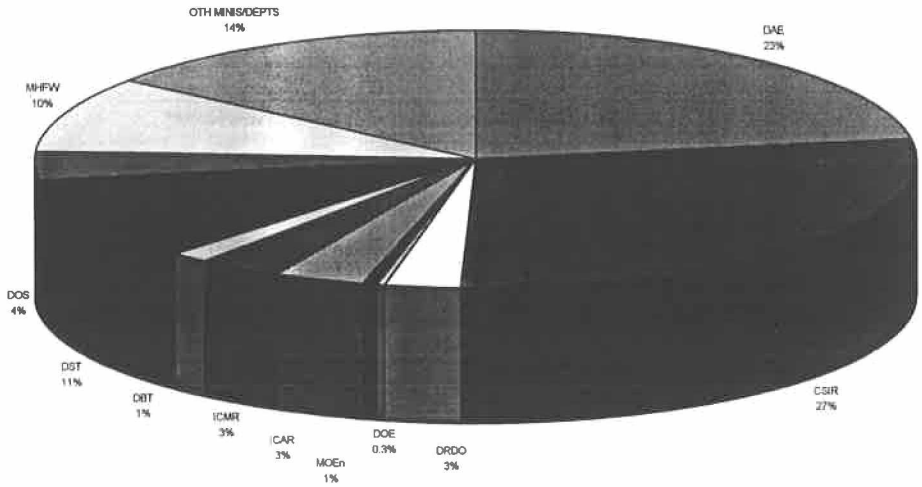


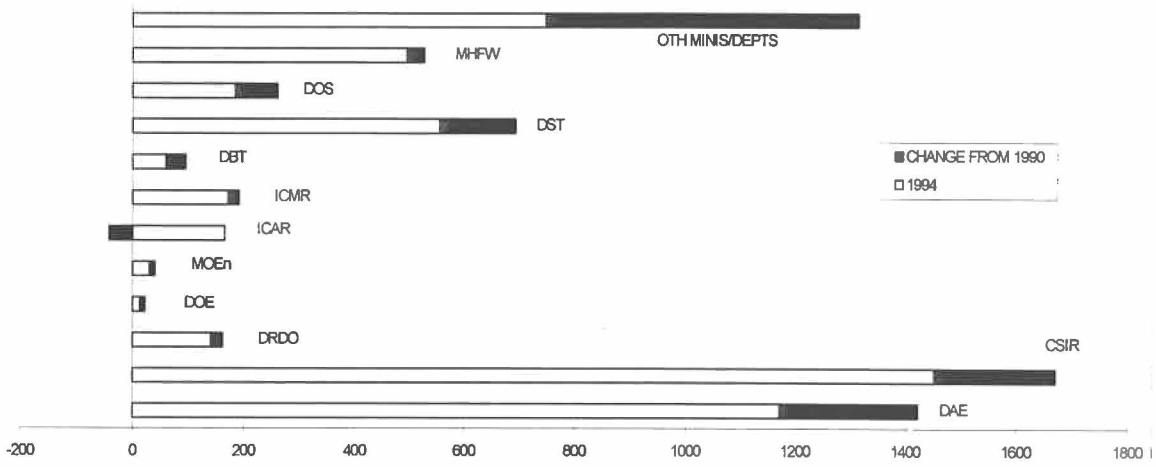
Fig 6.2b Percentage Contributions Among Major Scientific Agencies 1994



SCI Data for India 1990 - 94 : Publication

** SCI Data for India 1990 - 94 : Publication Output*

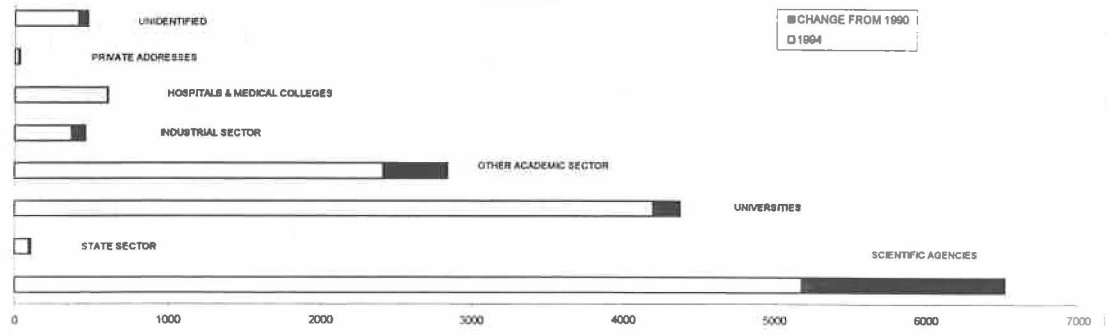
Fig 6.3a : Indian Scientific Publication Output & Change Major Scientific Agencies (1990-1994)



Amongst the Major Scientific Agencies there is a obvious increase in most cases with almost all the agencies showing a positive change. ICAR, however, is the only agency which has upset this trend. Though CSIR and DAE are the top contributors their induvidual growth is less than the growth of the other ministries and departments put together.

All the Major sectors have registered an increase from 1990 to 1994. The Major Scientific Agencies have shown a significant increase in the contribution. The other noticable positive changes are of other academic sectors and Universities.

Fig 6.3b 1: Indian Scientific Publication Output & Change fin Major Sectors (1990-1994)



** SCI Data for India 1990 - 94 : Publication Output*

6.3 The Academic sector

Compared to the 1990 values, we see that the output of the ***Academic sector*** has fallen by **4** percentage points, accounted for by a decline of **5.4** percentage points in the ***university*** output and an increase of 0.4 percentage points in the ***other Academic*** sector, which includes the Indian Institutes of Technology, deemed universities and Centres for Advanced Study. The ***University sector*** has an average IF (***1.1***) that is lower than the national average, (***1.3***) while in the ***Other Academic*** sector the average IF is better (***1.26***) but still lower than the national average.

6.4 The Industrial sector

The ***Industrial sector*** accounts for less than ***3 percent*** of the publications. The largest output is in the area of ***Medicine***, which accounts for more than half the papers published in this sector. The ***Average Impact Factor 1.53*** is better than the ***national average of*** 1.33.

6.5 Private Addresses

The number of papers from private addresses is a small proportion of the total , being only ***0.1%*** in 1990. This number has doubled in 1994. These represent persons who are working from outside organised science. and could be retired persons or those otherwise not employed. The average Impact of these papers is high, much higher than the national average.

6.6 Performance of the sectors in different disciplines

The change in publication output of the major scientific Agencies are shown in Table 6.4. With the exception of ***ICAR***, all the agencies have shown an increased output in 1994. In Table 6.5 we show the sectors/agencies which have performed well in the different disciplines either in terms of output or average Impact Factor of its papers. Except for ***Medicine and Engineering*** , and related areas of ***Computers*** and ***Materials***, the ***Universities*** have the highest contribution in all the areas. In ***Medicine*** the ***Hospitals make the largest contribution***, while ***the other Acdemic sector*** (including IIT's) ***have***

the highest output in Engineering, Computers and Communication, and Material Science.

6.7 Impact Factors of Sectors/Agencies in different disciplines.

The Department of Atomic Energy (DAE) had the highest impact in Physics, and second highest impact in Computers, Engineering, and Biomedical Research.

The Department of Science and Technology (DST) had the highest impact in Chemistry and Materials Science.

The Department of Bio-technology (DBT) had the highest impact in Bio-medical Research and Agriculture, and the second highest impact in Medicine and Biology.

DRDO had the second highest rank by impact in Materials Science and the third from the top in Engineering.

The multi-disciplinary papers had very high impact, those from the Ministry of Health and Family Welfare (associated institutes) having the highest impact (> 10) followed by the Medical sector and papers from private addresses.

Table 6.4 :Sector-wise change from 1990 to 1994 : Major Scientific Agencies

SECTORS	CHE	PHY	MED	BMD	ENG	BIO	GEO	MUL	AGR	MTL	MAT	COM	TOT	CHANGE
MAJOR SCIENTIFIC AGENCIES														
DAE	22	176	10	-7	28	4	10	9	-4	18	-11	-3	252	27.45%
CSIR	105	39	-28	59	-4	6	-6	19	8	18	-1	3	218	17.68%
DRDO	2	15	-2	5	1	-2	4	1	-1	-2	0	0	21	17.65%
DOE	0	1	-1	0	6	0	1	2	0	0	0	0	9	225.00%
MOEn	0	2	0	0	0	5	5	1	-3	0	0	0	10	50.00%
ICAR	-1	-1	-4	7	-3	1	-2	-6	-32	-1	0	0	-42	-20.29%
ICMR	0	0	-8	19	0	5	0	1	3	0	0	1	21	14.09%
DBT	0	0	9	17	0	4	0	2	4	0	0	0	36	156.52%
DST	18	49	1	10	1	1	19	34	0	7	0	0	140	33.90%
DOS	-2	23	0	-3	16	-1	39	7	0	1	-2	-1	77	72.64%
MHFW	2	-1	-1	27	0	4	0	2	-1	-1	0	2	33	7.17%
OTHER MINISTRIES/DEPTS	31	53	411	85	24	16	26	34	4	10	31	21	746	316 76%

Table 6.5 : Performance of the Sectors in the Different Disciplines : 1994

Mathematics		Physics	
High Output	***High Impact***	***High Output***	***High Impact***
Universities (79)	Unidentified(.75)	Universities (999)	DAE (2.0)
Other Academic(51)	Other Min & Dep(.6)	DAE (623)	DOS (1.86)
DAE (30)	Other Academic(.53))	Other Academic(611)	DST (1.86)
Chemistry		**Biology**	
High Output	***High Impact***	***High Output***	***High Impact***
Universities (1144)	DST(1.6)	Universities (307)	MHFW(9.0)
Other Academic (610)	Other Min. (1.6)	CSIR (68)	DBT (8.5)
CSIR (488)	Other Acad. (1.6)	Other Acad. (53)	Hosp & med Coll (5)
Earth & Space Sciences		**Agriculture**	
High Output	***High Impact***	***High Output***	***High Impact***
Universities(160)	State Sector(1.2)	Universities (132)	DBT (1.7)
CSIR(102)	DOS (1.1)	ICAR (43)	MHFW (1.1)
DOS (72)	ICAR (1.1)	CSIR (41)	ICMR(0.95)
Medicine		**Bio-medical Research**	
High Output	***High Impact***	***High Output***	***High Impact***
Hosp. & Med coll (500)	Unidentified (2.9)	Universities(469)	DBT (3.2)
Other Min. & Dept (411)	DBT (2.5)	CSIR (207)	DAE (2.9)
MHFW (392)	DAE (2.4)	Other Acad. (164)	Unidentified (1..9)
Engineering		**Computer & Communication**	
High Output	***High Impact***	***High Output***	***High Impact***
Other Acad. (452)	Hosp. & Med coll(.74)	Other Acad. (67)	CSIR (1.27)
Universities(265)	DAE(.68)	Universities (25)	DAE (0.99)
CSIR (99)	DRDO (.67)	Other Min. & Dept (21)	MHFW (0.89)
Material Science		**Multidisciplinary**	
High Output	***High Impact***	***High Output***	***High Impact***
Other Acad. (134)	DST (1.13)	Universities (178)	MHFW (10.3)
Universities (110)	DRDO (0.96)	Other Acad. (105)	Hosp. & Med coll(5.0)
CSIR (83)	Other Acad. (0.82)	CSIR (93)	Private Addresses (4.85)

7 Scientific Output of States

In this chapter we have examined the output of 28 states and Union Territories in India in the different scientific disciplines for the years 1990 & 1994. Given that there is a large variation in the size of the states, their population, scientific outlay, as well as the distribution of scientific institutions within the states, it is expected that there will be wide variations in scientific output from these states.

Table : States and Union territories of India

ANDAMAN & NICOBAR	AND	MADHYA PRADESH	MAP
ANDHRA PRADESH	APR	MAHARASHTRA	MHA
ARUNACHAL PRADESH	ARN	MANIPUR	MAN
ASSAM	ASM	MEGHALAYA	MEG
BIHAR	BIH	MIZORAM	MIZ
CHANDIGARH	CHD	ORISSA	ORI
DELHI	DEL	PONDICHERRY	PON
GOA	GOA	PUNJAB	PNJ
GUJARAT	GUJ	RAJASTHAN	RAJ
HARYANA	HAR	SIKKIM	SIK
HIMACHAL PRADESH	HIM	TAMIL NADU	TAM
JAMMU & KASHMIR	J&K	TRIPURA	TRI
KARNATAKA	KAR	UTTAR PRADESH	UPR
KERALA	KER	WEST BENGAL	WBN

7.1 Scientific publications from Indian states

There is a wide variation seen in the volume of output from different states and Union Territories, given their intrinsic differences, as well as differences in size (Fig. 7.1a,b).

The scientific output normalised by the population of the state is shown in Section 7.2, Fig.7.1c.

The states with the highest volume of published work in 1990 were *Maharashtra*, *UP*, *West Bengal* and *Delhi* with more than 1000 papers each, accounting for over 50 percent of India's output in the *SCI*. Since 1994 they have been joined by *Karnataka* and *Tamil Nadu*, the latter overtaking *Andhra Pradesh* to obtain the sixth rank in terms of overall production. These states together account for almost 70 percent of India's output.

The highest growth in publications since 1990 has been in the southern and western states of *Karnataka, Tamil Nadu* and *Maharashtra*, whereas almost all the northern states, *Rajasthan, Uttar Pradesh, Chandigarh, Himachal Pradesh, Jammu and Kashmir* have declined in terms of scientific output. Other states that have shown an increase are *Madhya Pradesh*, *Gujarat* and *Andhra Pradesh.* (Table 7.1c and Section 7.3).

The publication output of the Indian states in different disciplines in the *Science Citation Index* is shown in Table 7.1a,b for the years 1990 and 1994. The performance of the states in terms of output in different disciplines is shown in a series of 12 graphs in Section 7.7. Research profiles of individual states, including output in different disciplines, areas of high output, growth or decline and extent of domestic and foreign collaboration are shown in Section 7.8

The Average Impact Factor of each state has been determined in each of the 12 disciplines as well as in all fields combined. These have been compared with the national averages for Impact Factor in each of these fields. These results are summarized in Sections 7.5 and 7.6. The change in productivity and IF between 1990 and 1994 have been indicated.

Fig 7.1a Statewise Output for 1994 (All Disciplines)

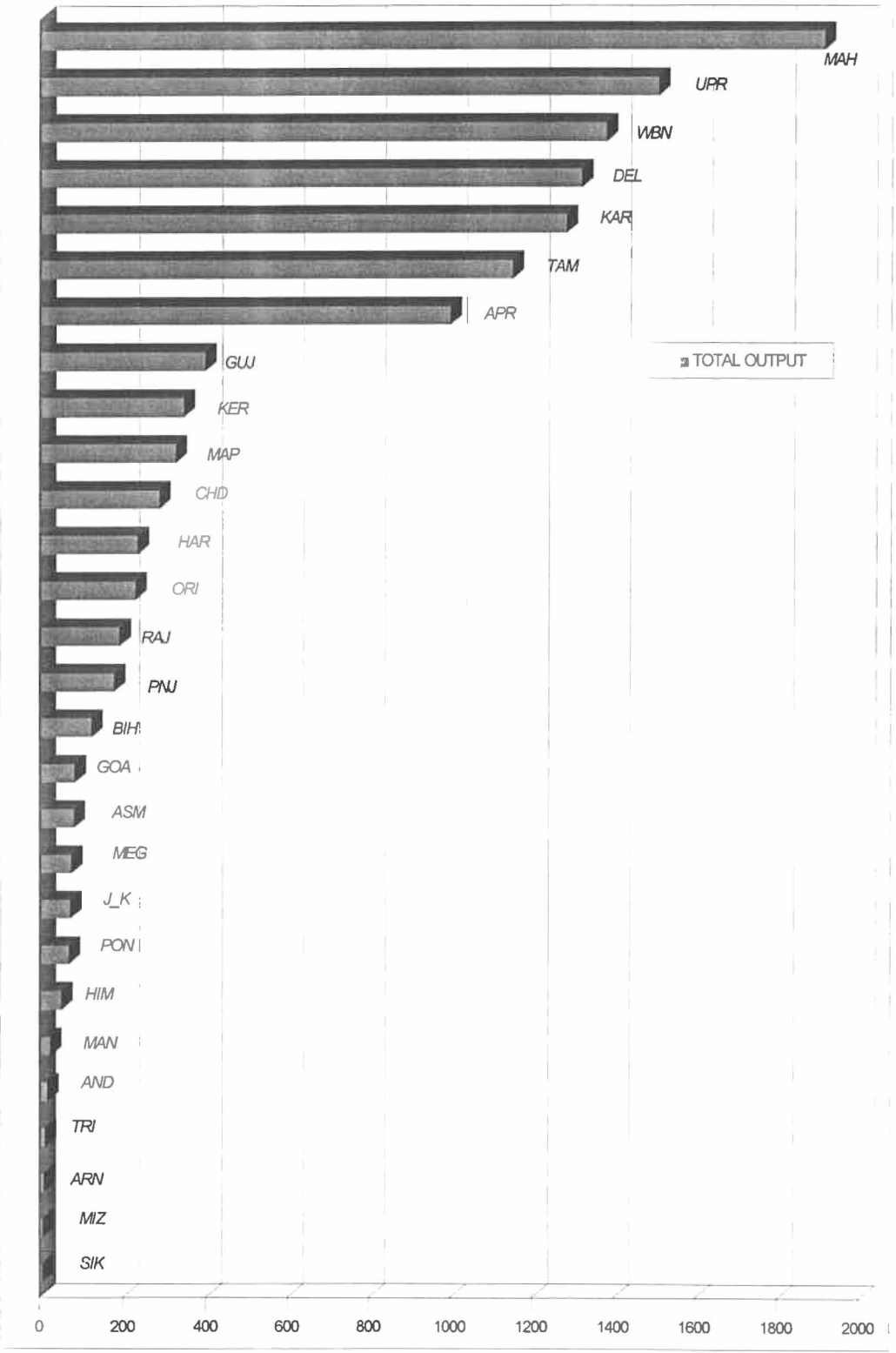
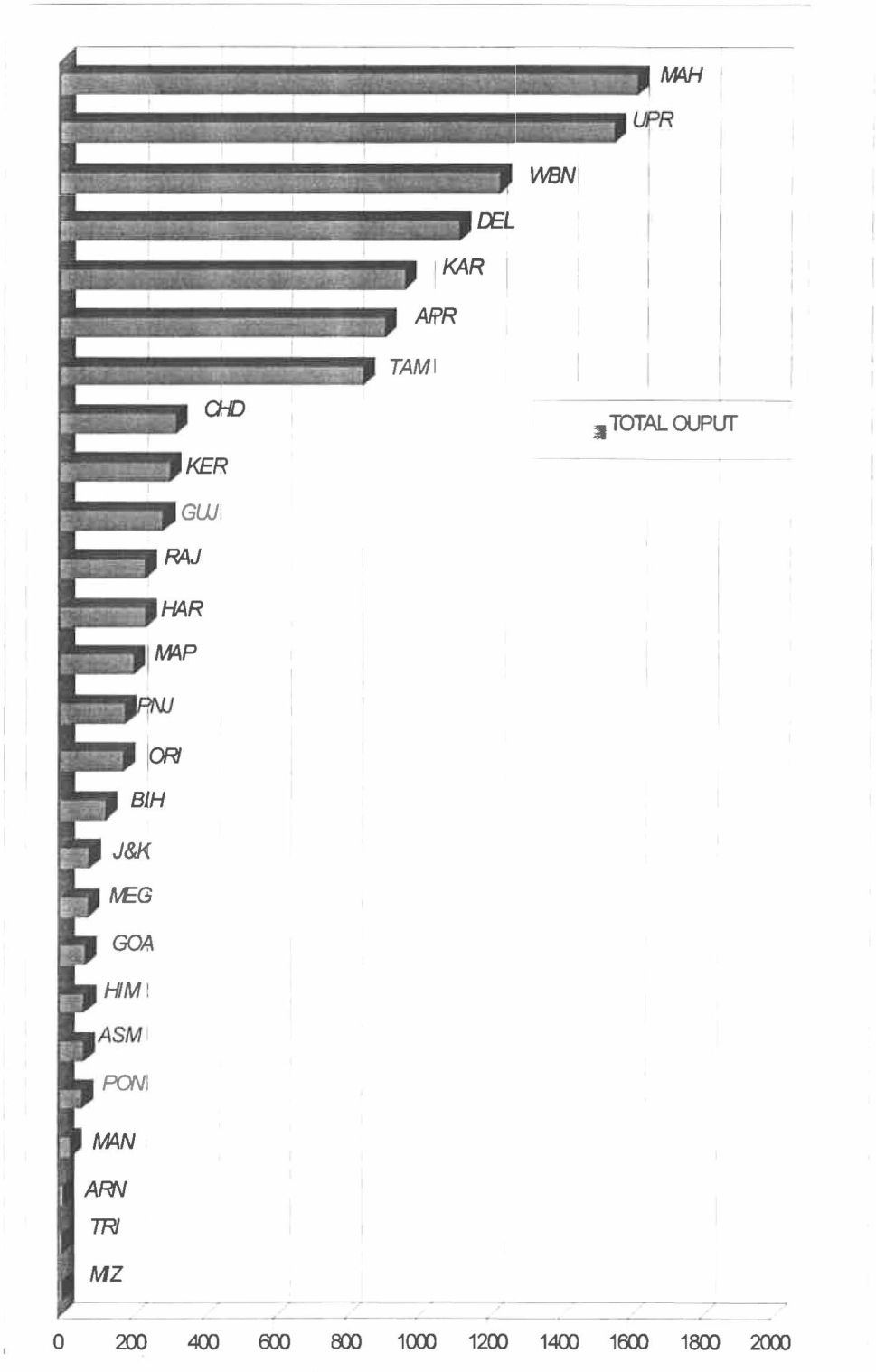


Fig 7.1b Statewise Output for 1990 (All Disciplines)



7.2 Scientific output of states per unit Population

When scaled for size differences by the population in each state, sharp differences emerge (Figure 7.1c). The scaled value is a measure of science orientation in the region. The Union territories, Chandigarh, Delhi , Pondicherry and Goa and Andaman- Nicobar have higher output per lakh population, Chandigarh leading with 43 papers, followed by Delhi with 14 papers and Pondicherry with 8 papers.

Among the larger states, Karnataka leads with close to 3 paper per lakh population, Maharashtra with 2.3 papers, and Tamil Nadu and West Bengal with 2 papers each.

Among the smaller states, Meghalaya has a higher per capita output compared to the larger states with an average of 4 papers per lakh persons.

As the major institutions where much of the scientific research is conducted are located in the metropolitan areas, a clearer picture would emerge if the distribution of scientific output over cities was mapped. This will be taken up in a future exercise.

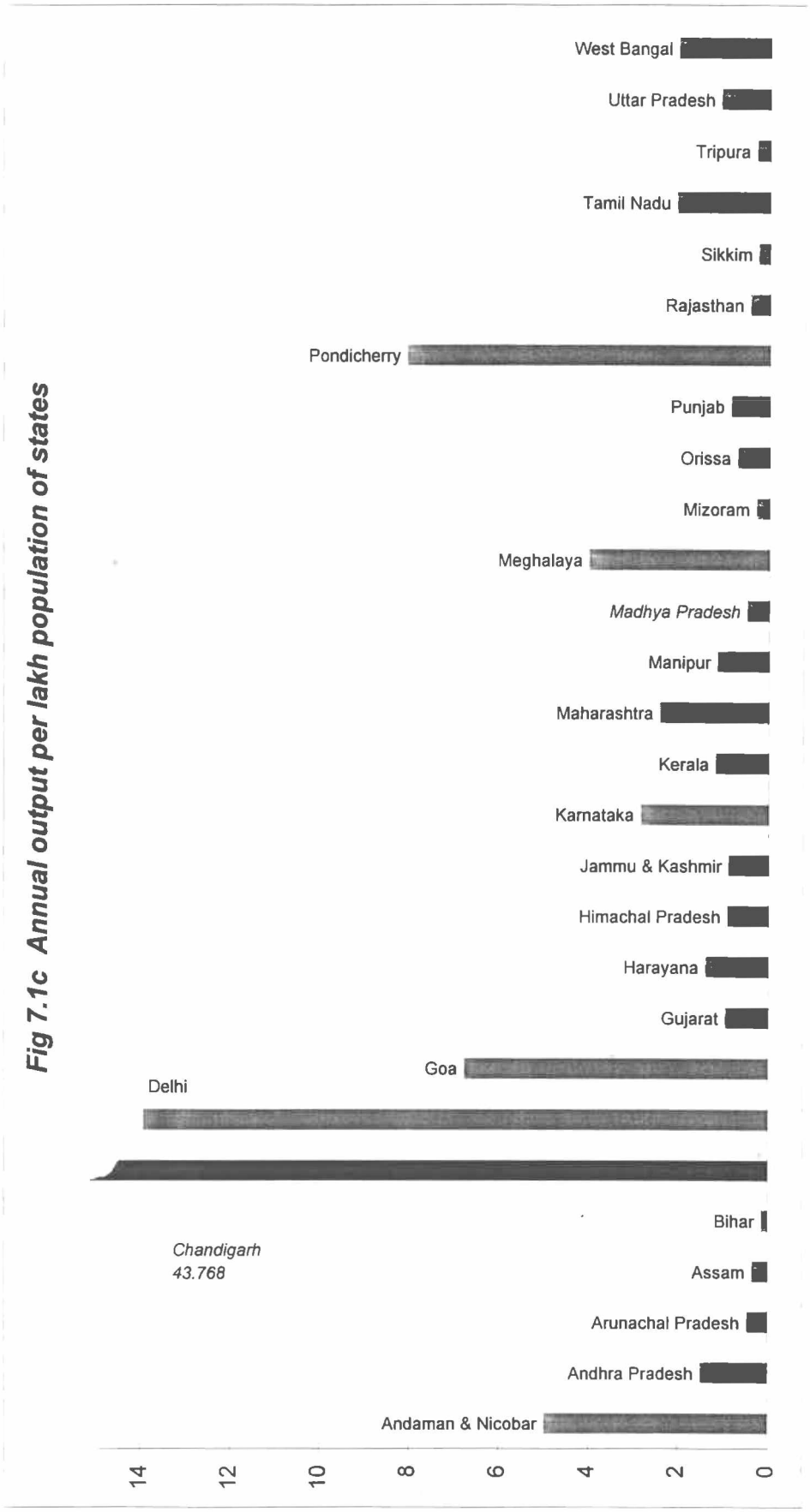


Fig 7.1c Annual output per lakh population of states

7.3 Changes in State output in Major Disciplines

Even though national output of scientific publications has increased in all the disciplines except Agriculture, there is both growth and decline in disciplines at the state level. This may be indicative of either fluctuation or a shift in emphasis or quality. The output of the states in different disciplines in 1990 and 1994 are shown in table 7.1a,b and change in state output in different disciplines is shown in Table 7.1c. Graphs for each discipline showing the position of each state in terms of output and growth or decline in the discipline are displayed in Section 7.7.

From Table 7.1a, it may be seen that the ***highest output*** in Physics, Chemistry, Computers, Engineering, Biology and Medicine are from Maharashtra, W. Bengal , UP, Tamil Nadu, Karnataka and Delhi.

In Agriculture it is from Andhra pradesh, Karnataka, UP, W. Bengal, Delhi and Haryana.

The ***maximum growth*** has taken place in Physics (342 papers), followed by Biomedical Research (308) and Engineering (234). Tamil Nadu is growing in all areas except Agriculture, while Rajasthan and UP have declined in 7-8 out of 12 disciplines.

The ***highest increase*** has been in Physics from Maharashtra (109 papers), in Chemistry in Tamil Nadu (87)and Maharashtra (82), Physics in West Bengal (70) , Biomedical Research in Delhi (63) and Karnataka (55), and Clinical medicine in Tamil Nadu (60), Engineering and Materials Science in Karnataka (49, 27) and Tamil Nadu (33, 16). Contributions in Multi disciplinary journals appears to have increased in Karnataka, Maharashtra and UP. Computers, a small field, appears to be growing in almost all the states, more significantly in West Bengal (18).

The ***major decline*** has been in Clinical medicine in Chandigarh (-52) and Maharashtra (-34), in Chemistry in Andhra (-45) and in UP (-32), in Agriculture in Haryana (-32) and UP (-32), in Physics in UP (-23), in Biology in West Bengal(-22) and UP (-21).

Table 7.1a : Publication Output for States in Different Disciplines SCI Data 1994

STATE	MAT	PHY	CHE	BIO	GEO	AGRI	MED	BMD	ENGG	COMP	MTL	MUL	TOT	*TOTAV_IF*
AND		1	1	2	2		7		1				14	***0.587***
APR	4	174	261	82	65	46	90	123	61	3	39	45	993	***1.481***
ARN		2							2				4	***1.986***
ASM	2	16	26	4	3	3	4	9	6		1	3	77	***0.709***
BIH	1	17	10	7	12	2	11	11	27	3	11	7	119	***0.972***
CHD	3	38	39	3	7	1	119	54	5			12	281	***1.587***
DEL	39	251	142	69	56	23	362	157	95	16	37	65	1312	***1.544***
GOA	2	1	6	12	34		5	3	4			12	79	***1.053***
GUJ	2	90	107	10	66	6	53	21	16		6	15	392	***1.268***
HAR		23	78	25	9	21	28	16	15	2	3	9	229	***0.866***
HIM	2	9	8	11	1	8	1	4	1		1	1	47	***0.784***
J_K		17	6	4	9	2	16	6			4	4	68	***0.877***
KAR	17	278	223	36	31	49	127	165	134	22	59	134	1275	***1.467***
KER	4	45	86	19	25	8	62	22	28		24	17	340	***1.118***
MAP	3	97	69	14	11	6	42	36	20	1	10	11	320	***1.1***
MAH	43	533	509	45	71	11	269	142	144	13	45	79	1904	***1.574***
MAN		7	4		2	1	4	2				1	21	***0.6***
MEG		24	24	7	2	2		9				3	71	***0.999***
MIZ		1					1						2	***0.38***
ORI	5	92	56	8	6	7	22	10	14		1	3	224	***1.338***
PON		3	10	6	4		34	5	1		1	1	65	***1.689***
PNJ	2	27	30	16	5	32	22	29	7		1	2	173	***0.959***
RAJ	2	45	57	12	3		35	8	10	2	5	7	186	***1.203***
SIK								1					1	***0.517***
TAM	23	227	239	55	22	14	213	94	127	13	66	51	1144	***1.147***
TRI		1	2	2	1	1						1	8	***0.59***
UPR	26	226	322	107	88	33	234	148	187	11	33	86	1501	***1.177***
WBN	23	455	306	41	47	22	114	145	104	34	61	21	1373	***1.256***
TOTAL	***203***	***2700***	***2621***	***597***	***582***	***298***	***1875***	***1220***	***1009***	***120***	***408***	***590***	***12223***	*1.333*

Table 7.1b : Publication Output for States in Different Disciplines - SCI Data 1990

STATES	MATHS	PHYS	CHEM	BIO	EARTH	AGRI	MED	BIOMED	ENGG	COMP	MTL	MULTI	TOT	AVG_IF
APR	13	156	306	56	42	50	51	91	60		39	36	900	1.204
ARN			5	1									6	0.676
ASM		23	24	3	2	3	2	4	2		1	1	65	1.007
BIH		24	14	10	14	7	11	9	24	1	5	4	123	0.799
CHD	3	25	39	8	5	4	171	46	5			10	316	1.301
DEL	19	217	134	50	38	14	363	94	78	6	39	55	1107	1.323
GOA		4	1	6	41	1	3	2	3			9	70	1.196
GUJ	5	56	82	14	34	9	36	20	2		12	13	283	1.203
HAR	1	24	70	20	6	53	24	17	9		1	7	232	0.792
HIM	1	8	8	9	1	11	16	6	2			4	66	1.028
J&K		10	14	14	2	2	20	13	1			5	81	1.330
KAR	27	257	163	37	18	39	98	110	85	12	32	78	956	1.266
KER	2	49	70	24	15	13	48	12	15	1	26	25	300	0.955
MAP	1	45	65	12	9	4	28	21	7		2	8	202	0.893
MAH	41	424	427	32	39	26	303	109	116	10	39	41	1607	1.553
MAN		19	4	2		1		2			1		29	0.786
MEG	1	24	29	12	2	1	1	1	1			3	75	1.199
MIZ			2									1	3	0.335
ORI	1	54	51	14	6	7	9	11	12		4	2	171	1.197
PON	1	5	10	5			29	6	1		1	1	59	0.663
PNJ	3	31	42	17	1	27	33	13	4		2	5	178	0.864
RAJ	3	52	81	16	6	7	31	5	20		3	10	234	1.007
TAM	11	216	152	37	10	21	153	54	94	9	50	34	841	1.217
TRI	1		1	2									4	0.550
UPR	16	249	354	128	95	65	248	131	156		42	57	1541	1.024
WBN	25	385	283	63	44	18	91	134	77	16	62	22	1220	1.262
TOTAL	175	2357	2431	592	430	383	1769	911	774	55	361	431	10669	1.2160

Table 7.1c : Change in the Output of States in the Major Disciplines ('90-'94)

FIELD1	MAT	PHYS	CHEM	BIO	GEO	AGRI	MED	BMD	ENGG	COMP	MTL	MUL	TOT
KAR	-10	21	60	-1	13	10	29	55	49	10	27	56	319
TAM	12	11	87	18	12	-7	60	40	33	4	16	17	303
MAH	2	109	82	13	32	-15	-34	33	28	3	6	38	297
DEL	20	34	8	19	18	9	-1	63	17	10	-2	10	205
WBN	-2	70	23	-22	3	4	23	11	27	18	-1	-1	153
MAP	2	52	4	2	2	2	14	15	13	1	8	3	118
GUJ	-3	34	25	-4	32	-3	17	1	14		-6	2	109
APR	-9	18	-45	26	23	-4	39	32	1	3	0	9	93
ORI	4	38	5	-6	0	0	13	-1	2		-3	1	53
KER	2	-4	16	-5	10	-5	14	10	13	-1	-2	-8	40
ASM	2	-7	2	1	1	0	2	5	4		0	2	12
GOA	2	-3	5	6	-7	-1	2	1	1			3	9
PON	-1	-2	0	1	4		5	-1	0		0	0	6
TRI	-1	1	1	0	1	1						1	4
MIZ		1	-2				1					-1	-1
ARN		2	-5	-1					2				-2
HAR	-1	-1	8	5	3	-32	4	-1	6	2	2	2	-3
BIH	1	-7	-4	-3	-2	-5	0	2	3	2	6	3	-4
MEG	-1	0	-5	-5	0	1	-1	8	-1			0	-4
PNJ	-1	-4	-12	-1	4	5	-11	16	3		-1	-3	-5
MAN		-12	0	-2	2	0	4	0			-1	1	-8
J_K		7	-8	-10	7	0	-4	-7	-1		4	-1	-13
HIM	1	1	0	2	0	-3	-15	-2	-1		1	-3	-19
CHD	0	13	0	-5	2	-3	-52	8	0			2	-35
UPR	10	-23	-32	-21	-7	-32	-14	17	31	11	-9	29	-40
RAJ	-1	-7	-24	-4	-3	-7	4	3	-10	2	2	-3	-48
TOT	28	342	189	3	150	-85	99	308	234	65	47	159	1539

7.4 Average Impact Factor of States (1994)

The average impacts are calculated and tabulated in Table 7.2a,b using 1994 IF values. States with average impact higher than the national average (1.33) are, Chandigarh (1.59), Delhi (1.54), Pondicherry (1.69), Maharashtra (1.57), Karnataka (1.47) Andhra (1.48), and Orissa (1.34).

The highest national averages for impact factors are in Medicine (1.917) (with seven states having an IF higher than 2), Physics (1.607) and Biomedical Research (1.576). States with higher than average impact in each of these areas are,

Medicine	Andhra (2.66), .Bihar (2.82), Delhi (1.91), Goa (2.66), Gujarat (2.23), Karnataka (2.34), Rajasthan (2.35)
Physics	Arunachal (3.23), Chandigarh (2.12), Karnataka (1.98), Maharashtra (1.92)
Biomedical	Goa (3.39), Delhi (1.85), Andhra (1.67),

The states with more than average impact in all fields combined in 1994 are

Pondicherry, Chandigarh, Maharashtra, Delhi, Andhra, Karnataka and Orissa.

The states with more than average impact in at least half the fields in 1994 are

Andhra, Karnataka (10 areas), Maharashtra (9 areas), Delhi (6 areas), West Bengal (6 areas), closely followed by Bihar (5 areas).

Table7.2a : Average Impact Factor Of States In Different Disciplines : SCI Data 1994

STATE	MATHS	PHYS	CHEM	BIO	EARTH	AGRI	MED	BMD	ENGG	COMP	MTL	MULTI	TOT
AND	0	0.569	2.277	1.106	0.371	0	0.324	0	0.152	0	0	0	0.587
APR	0.502	1.44	1.677	1.694	0.818	0.696	2.663	1.668	0.642	1.01	0.821	0.82	1.481
ARN	0	3.233	0	0	0	0	0	0	0.739	0	0	0	1.986
ASM	0.144	0.644	0.644	1.073	0.567	0.842	1.626	0.711	0.712	0	0.716	0.271	0.709
BIH	0.852	1.046	1.469	0.86	0.209	1.103	2.822	1.111	0.508	1.38	0.782	0.271	0.972
CHD	0.366	2.121	1.209	5.388	0.444	1.342	1.912	1.177	0.498	0	0	0.246	1.587
DEL	0.502	1.529	1.198	2.451	0.731	0.885	2.057	1.853	0.53	0.651	0.89	1.419	1.544
GOA	0.669	0.395	0.809	0.678	1.165	0	2.655	3.39	0.542	0	0	0.271	1.053
GUJ	0.339	1.504	1.085	0.759	1.057	0.487	2.233	1.498	0.481	0	0.511	0.269	1.268
HAR	0	0.931	0.687	0.634	0.624	0.765	1.849	1.404	0.364	0.266	0.865	0.334	0.866
HIM	0.339	1.135	0.871	0.743	0.467	0.638	0	0.9	0.633	0	0.741	0.271	0.784
J_K	0	1.053	0.361	1.098	0.44	0.324	1.067	1.401	0	0	0.775	0.494	0.877
KAR	0.457	1.975	1.512	1.183	0.89	0.736	2.335	1.962	0.655	0.84	1.014	0.623	1.467
KER	0.61	1.143	1.204	0.758	1.002	0.762	1.615	1.514	0.71	0	0.799	0.271	1.118
MAP	0.54	1.388	1.013	1.877	0.492	0.548	1.02	1.364	0.391	1.803	0.645	0.271	1.100
MAH	0.529	1.924	1.514	1.176	0.821	0.644	1.972	2.011	0.694	0.905	0.763	1.234	1.574
MAN	0	0.452	0.569	0	0.602	1.002	0.678	0.989	0	0	0	0.271	0.600
MEG	0	1.074	1.162	0.818	0.639	0.266	0	0.991	0	0	0	0.271	0.999
MIZ	0	0.76	0	0	0	0	0	0	0	0	0	0	0.380
ORI	0.447	1.896	0.862	1.134	1.077	0.711	1.546	1.032	0.618	0	0.357	0.26	1.338
PON	0	0.909	1.002	0.793	0.561	0	1.644	1.412	0.689	0	0.898	25.466	1.689
PNJ	1.576	1.08	0.472	1.761	1.827	0.618	1.297	1.018	0.429	0	0.66	0.271	0.959
RAJ	0.598	1.072	1.107	0.558	0.882	0	2.348	0.846	0.55	0.498	0.795	0.338	1.203
SIK	0	0	0	0	0	0	0	0.517	0	0	0	0	0.517
TAM	0.51	1.404	1.121	0.998	0.601	0.356	1.712	1.236	0.57	0.891	0.593	0.717	1.147
TRI	0	0.76	0.293	0.893	1.232	0.087	0	0	0	0	0	0.271	0.590
UPR	0.408	1.437	1.111	1.759	0.669	0.627	1.9	1.091	0.527	0.533	0.691	0.834	1.177
WBN	0.7	1.569	1.183	0.934	0.816	0.718	1.398	1.611	0.619	0.795	0.811	0.266	1.256
NATIONAL	**0.523**	**1.607**	**1.262**	**1.432**	**0.812**	**0.683**	**1.917**	**1.576**	**0.591**	**0.797**	**0.786**	**0.814**	**1.333**

Table 7.2b: Average Impact Factor Of States In Different Disciplines - SCI Data 1990

STATES	MATHS	PHYS	CHEM	BIO	EARTH	AGRI	MED	BMD	ENGG	COMP	MTL	MULTI	TOT_AVG
APR	0.434	1.214	1.343	0.952	0.892	0.814	1.585	1.460	0.770		0.733	1.591	1.204
ARN			0.720	0.457									0.676
ASM		0.965	1.132	0.676	1.356	1.009	0.533	1.049	1.035		0.716	0.271	1.007
BIH		1.096	0.675	0.552	0.681	0.971	0.787	0.961	0.731	1.380	0.666	0.263	0.799
CHD	0.478	1.886	0.811	0.837	0.784	1.015	1.388	1.033	0.601			2.850	1.301
DEL	0.500	1.408	0.892	1.232	1.033	0.715	1.744	1.672	0.617	0.506	0.679	0.937	1.323
GOA		0.837	0.442	0.922	0.894	1.089	1.843	1.435	0.209			3.070	1.196
GUJ	0.539	1.494	0.959	0.842	1.437	0.790	1.270	1.287	0.326		0.534	2.245	1.203
HAR	0.359	1.079	0.881	0.763	1.027	0.777	0.714	0.606	0.327		1.072	0.271	0.792
HIM	0.388	1.060	2.486	0.644	0.563	0.672	0.947	1.127	1.132			0.291	1.028
J&K		2.425	1.006	0.884	0.459	0.626	1.897	1.180	0.258			0.271	1.330
KAR	0.561	1.705	1.244	0.709	0.727	0.688	1.593	1.892	0.607	1.028	0.806	0.436	1.266
KER	0.433	0.841	0.989	0.789	1.009	0.531	1.671	1.082	0.555	0.691	0.948	0.302	0.955
MAP	0.339	1.034	0.746	1.059	0.767	0.528	0.714	1.663	0.686		0.444	0.326	0.893
MAH	0.498	1.848	1.371	0.877	0.942	0.760	2.009	1.583	0.696	0.515	0.756	3.071	1.553
MAN		0.617	1.344	0.984		0.683		1.161			0.741		0.786
MEG	0.380	1.123	1.633	0.721	0.927	0.714	0.702	1.597	0.930			0.271	1.199
MIZ			0.368									0.271	0.335
ORI	0.610	1.711	0.752	0.583	0.713	0.520	3.182	1.497	0.620		0.908	0.507	1.197
PON	0.339	1.066	0.352	0.618			0.645	1.221	0.152		0.444	0.237	0.663
PNJ	0.685	1.200	0.630	0.796	2.847	0.716	1.026	1.010	0.498		1.013	0.264	0.864
RAJ	0.429	1.285	0.809	0.888	0.734	0.601	1.905	0.990	0.523		0.709	0.267	1.007
TAM	0.367	1.301	1.079	0.892	0.758	0.596	2.294	1.214	0.597	0.714	0.658	0.270	1.217
TRI	0.610		0.355	0.617									0.550
UPR	0.553	1.238	0.846	0.800	0.828	0.705	1.490	1.162	0.589		0.695	1.606	1.024
WBN	0.546	1.513	1.123	0.809	0.806	0.615	1.952	1.556	0.590	0.635	0.723	1.886	1.262
NATIONAL	**0.506**	**1.467**	**1.091**	**0.850**	**0.914**	**0.721**	**1.688**	**1.440**	**0.625**	**0.713**	**0.729**	**1.203**	**1.216**

7.5 Performance of states with respect to National Averages

The performance of states may be compared with respect to quantity of output or quality of output (Impact factor). The smaller states may not produce as much as some of the larger states but their output may be of comparable quality.

The comparison shows that some states produce more than the national average and their quality is also higher than the national average. In Table 7.3 we have shown the states divided into four categories with reference to the national averages for productivity and impact , namely,

higher than average output and impact,

higher than average output but lower than average impact

lower than average output but higher than average impact

lower than average output and impact

7.6 Performance of states in Different Disciplines

The performance of the states varies with discipline. While some of the larger states produce papers in almost all the areas of science, their quality need not be uniformly high. The smaller states may concentrate on only a few disciplines. The performance of states with respect to national averages for output and impact in each of the 12 disciplinary areas are shown by dividing them into 4 categories as explained in Section 7.5 for the years 1994 and 1990 (Fig. 7.2a,b).

Table 7.3: Classification of States based on Output & Impact Factor 1990 and 1994

1990		Output			
		Above Average		Below Average	
Impact Factor	Above Average	Maharashtra West Bengal Delhi Karnataka	I	Jammu & Kashmir Chandigarh	IV
	Below Average	Uttar Pradesh Tamil Nadu Andhra Pradesh	II	GUJ, KER, MAP, HAR, ORI, RAJ, PNJ, BIH, GOA, ASM, MEG, PON, MAN, TRI, ARN, MIZ, AND, SIK, HIM	III

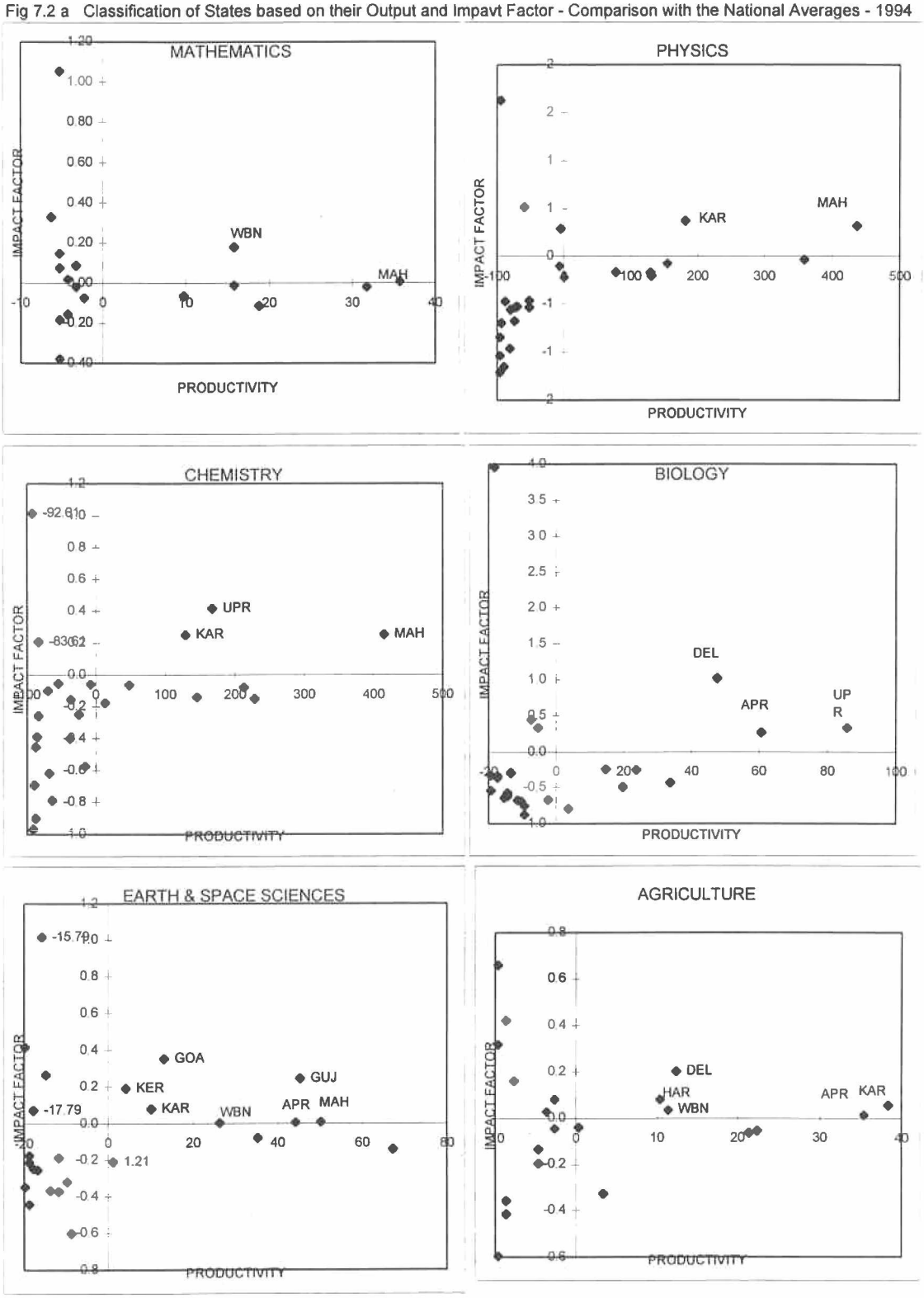
Without going into the actual figures of the Productivity and Impact Factor it is seen that ***Maharashtra, Delhi,*** *and* ***Karnataka*** *have maintained an above average productivity and Impact Factor from 1990 to 1994.* ***West Bengal*** *has however, lost out in 1994 as its Impact Factor has gone below the national average in 1994.* ***Andhra Pradesh*** *on the other hand has crossed over the average line for IF.*

Among the states with smaller output(below National Average), ***Chandigarh*** *has maintained its IF above the National Average in both 1990 & 1994. The IFs of* ***Pondicherry, Arunachal Pradesh*** *and* ***Orissa*** *have gone past the national avergage since 1990.* ***J&K's*** *IF fell below the national average between 1990 & 1994.*

I - both Output and Impact Factor above the National Average.
II - Ouput above the National Average but Impact Factor below the National Average
III - below the National Averages in both Output and Impact Factor.
IV- below the National Average in their Outputs but above National Average in Impact Factor

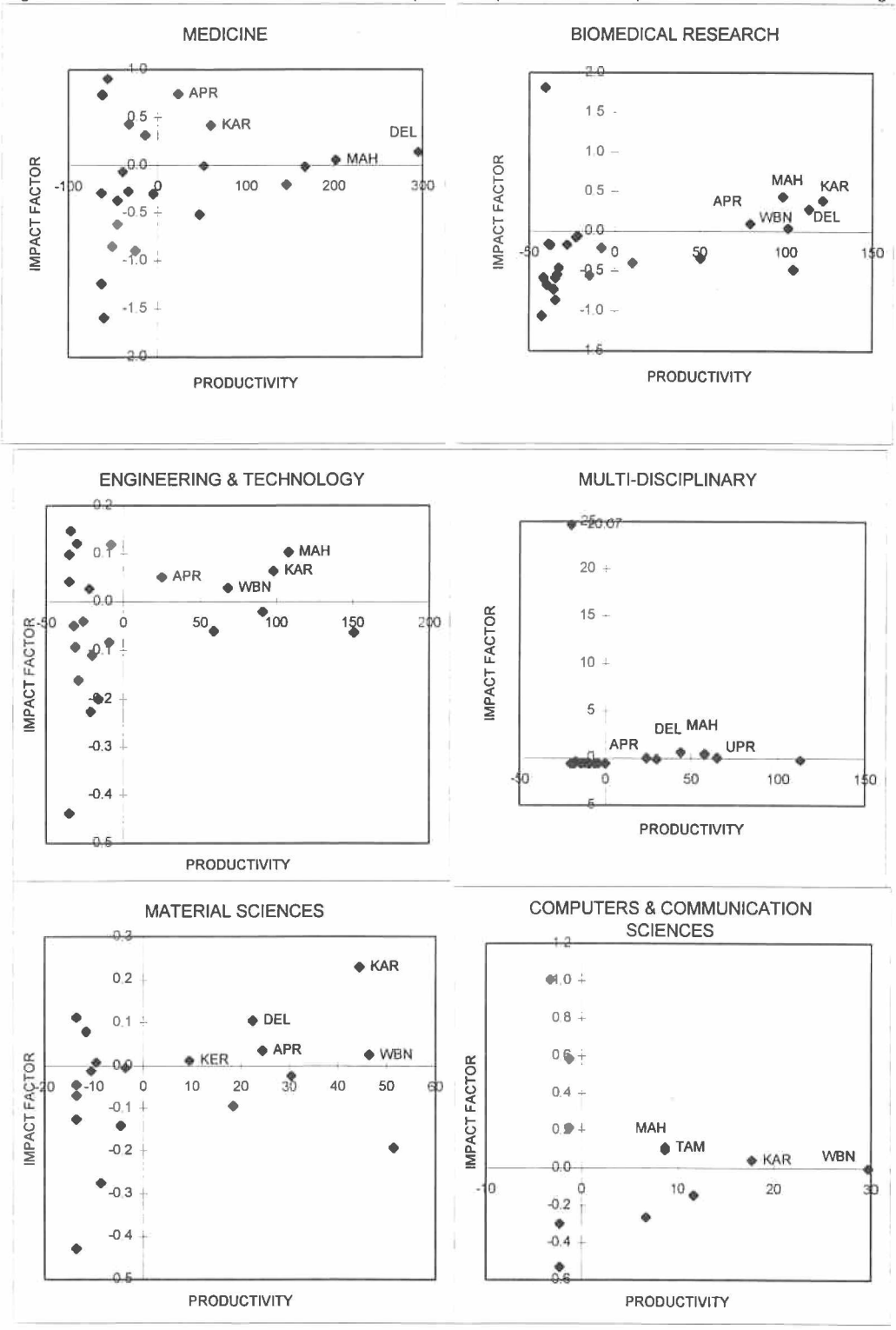
1994		Output			
		Above Average		Below Average	
Impact Factor	Above Average	Maharashtra Delhi Karnataka Andhra Pradesh	I	Pondicherry Chandigarh Orissa Arunachal Pradesh	IV
	Below Average	Uttar Pradesh Tamil Nadu West Bengal	II	GUJ, KER, MAP, HAR, RAJ, PNJ, BIH, GOA, ASM, MEG, J&K, MAN, TRI, MIZ, HIM	III

Fig 7.2 a Classification of States based on their Output and Impavt Factor - Comparison with the National Averages - 1994



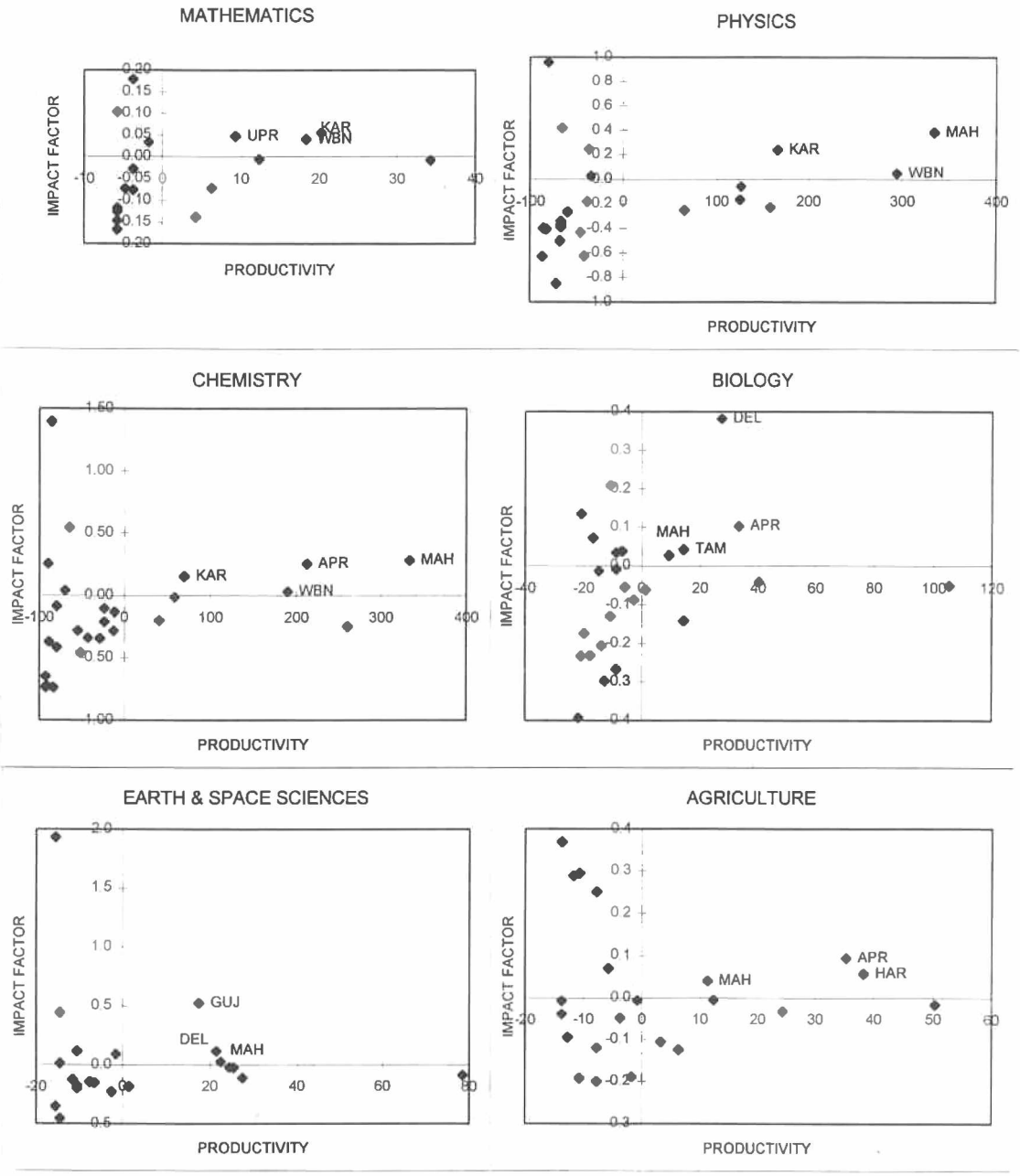
The general tr ends for 1994 are almost the same as was for 1990. Maharashtra and Karnataka feature in the Quadrant I nine of the twelve disciplinary categories. Karnataka has shifted six in 1990 to nine in 1994 which is a noticeable jump. Eleven of the twenty eight states occur in Quadrant I for atleast one discipline.

Fig 7.2 a Classification of States based on their Output and Impavt Factor - Comparison with the National Averages -



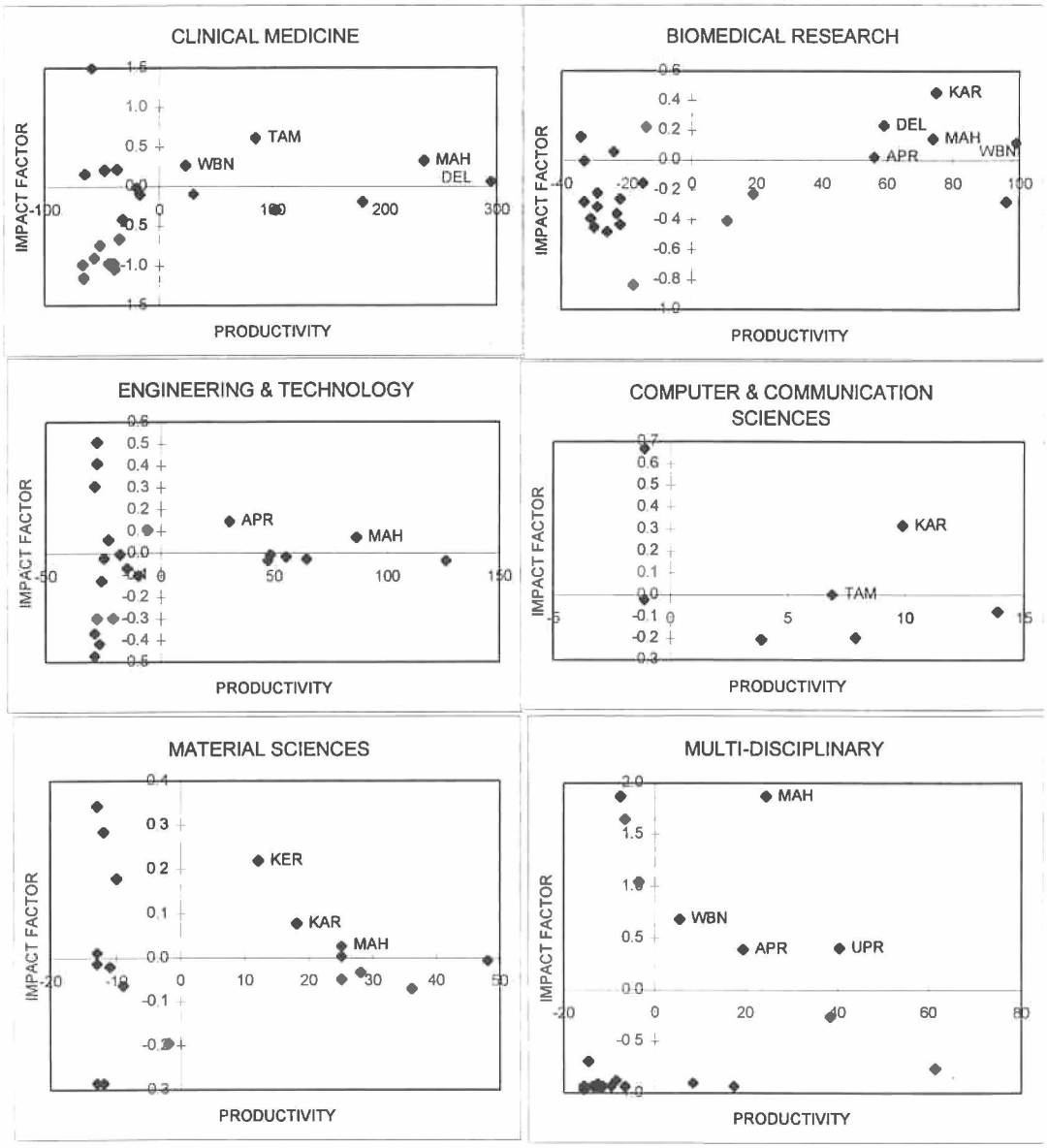
Five of this eleven occur only twice or less. Eigth of the eleven have shifts in their scores from 1990 but only Tamil Nadu has shown a negative shift. Goa is a new entrant in this club. 'West Bengal(+1), Karnataka(+3), Uttar Pradesh(+1), Delhi(+2) Andhra Pradesh(+2) and Kerala(+1) are the other states showing

Fig 7.2b Classification of States based on their Output and Impavt Factor - Comparison with the National Averages - 1990



In almost all the disciplines the general trends are that most of the states feature in either the Quadrant I (Contributions and Average IF above average) or in Quadrant II (both Contributions and Average IF below average). The number of states in the first Quadrant is usually less than five.

Fig 7.2b Classification of States based on their Output and Impavt Factor - Comparison with the National Averages - 1990



Maharashtra is in Quadrant I in nine of the twelve disciplinary categories. Karnataka, West Bengal, and Andhra Pradesh are next with a score of six each. Only ten of the twenty six states ever feature in the first Quadrant out of which three states occur only twice or thrice.

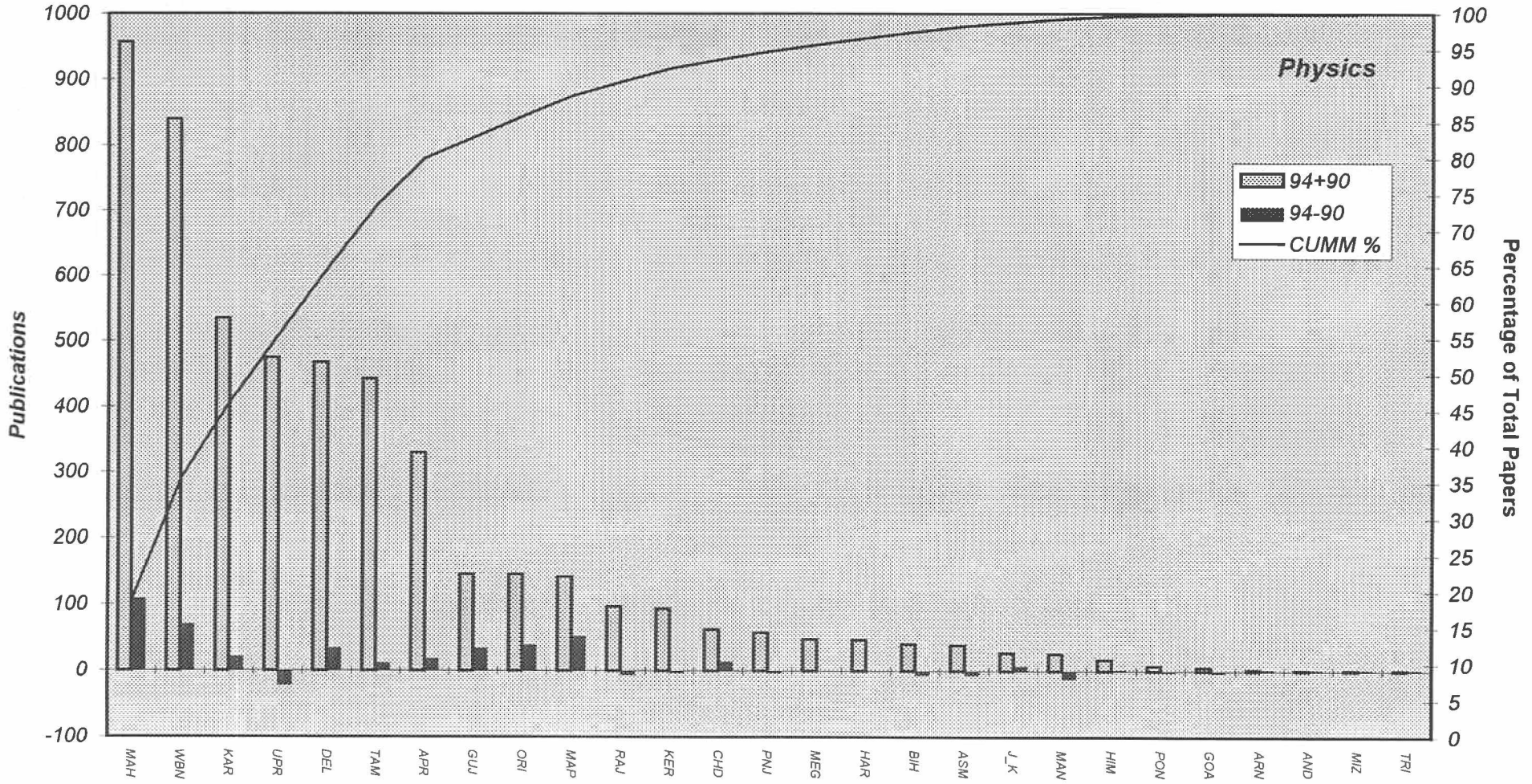
7.7 Graphical Display of State output in Different Fields

We have shown (ranked) the position of the state in terms of output separately in each discipline in a series of graphs. The change in the number of papers in the four year interval has also been indicated. The line graph indicates the cumulative percentage of the total output in that discipline covered by the top few states from a list arranged in descending order of output. In order to compensate for year to year fluctuations, we have used the cumulative output for the two years to compute the rank. The results can be summarised as follows:

Discipline	*High output*	*High Growth*	*Decline*
Mathematics	MAH, DEL, WBN	DEL, TAM, UPR	KAR, APR, GUJ
Physics	MAH, WBN, KAR	MAH, WBN, MAP	UPR, RAJ
Chemistry	MAH, UPR, WBN	TAM, MAH, KAR	APR, UPR, RAJ
Biology	UPR, APR, DEL	APR, DEL, TAM	WBN, UPR, J&K
Earth & Space	MAH, WBN, KAR	MAH, WBN, MAP	UPR
Agriculture	URP, APR, KAR	KAR, DEL,	UPR, HAR, MAH
Clinical Medicine	DEL, MAH, UPR	TAM, APR, WBN	CHD, MAH, HIM
Biomedical Research	UPR, WBN, KAR	DEL, KAR, TAM	J&K
Engineering & Tech	UPR, MAH, TAM	WBN, UPR, DEL	KER
Computer Science	WBN, KAR, MAH	WBN, UPR, DEL	KER
Material Sciences	WBN, TAM, KAR	KAR, TAM, MAP	UPR, GUJ, ORI
Multi Disciplinary	KAR, UPR, DEL	KAR, MAH, DEL	KER, RAJ, PNJ

stcht

States Output in Science Citation Index : 1990 & 1994



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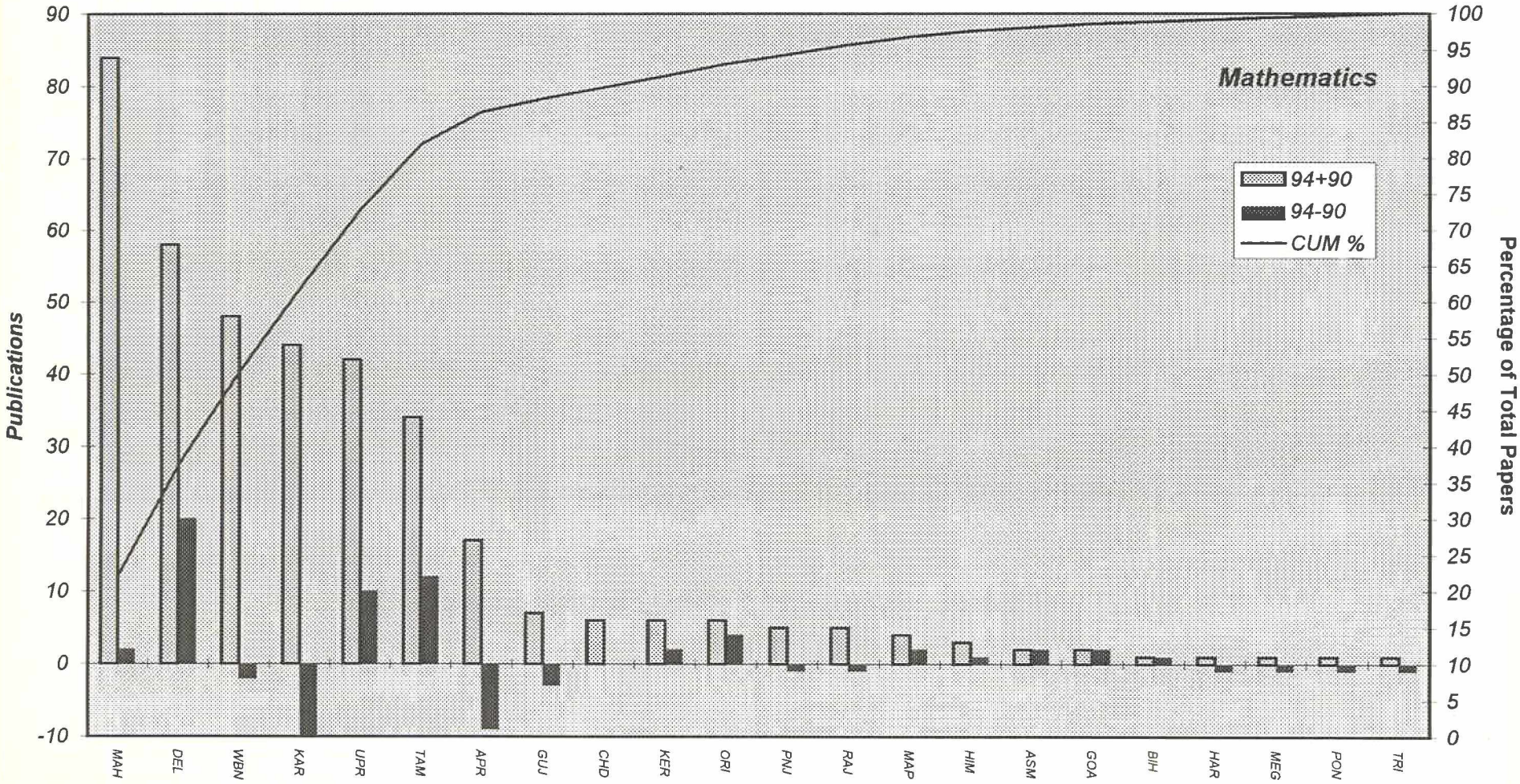
States Output in Science Citation Index : 1990 & 1994



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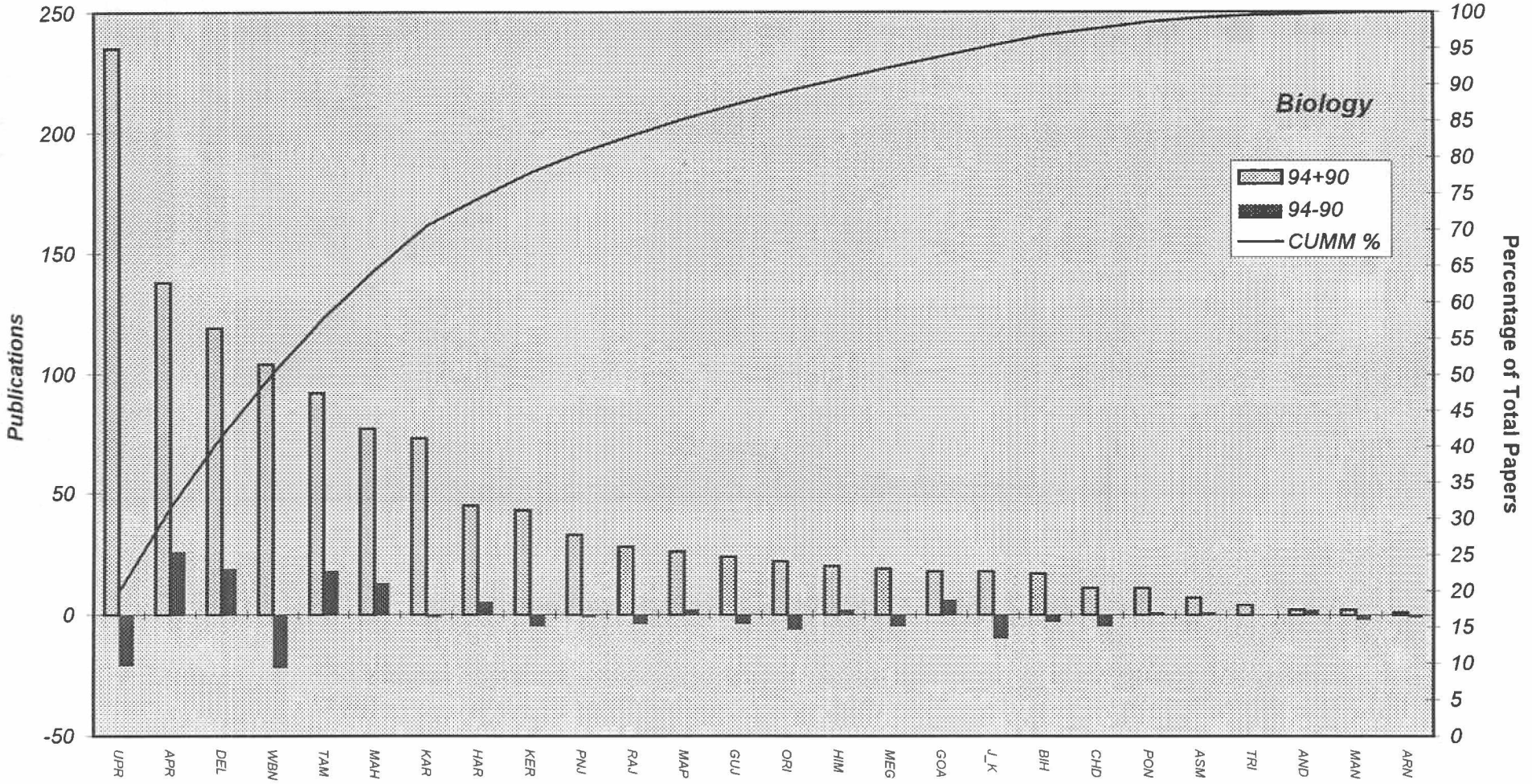
States Output in Science Citation Index : 1990 & 1994



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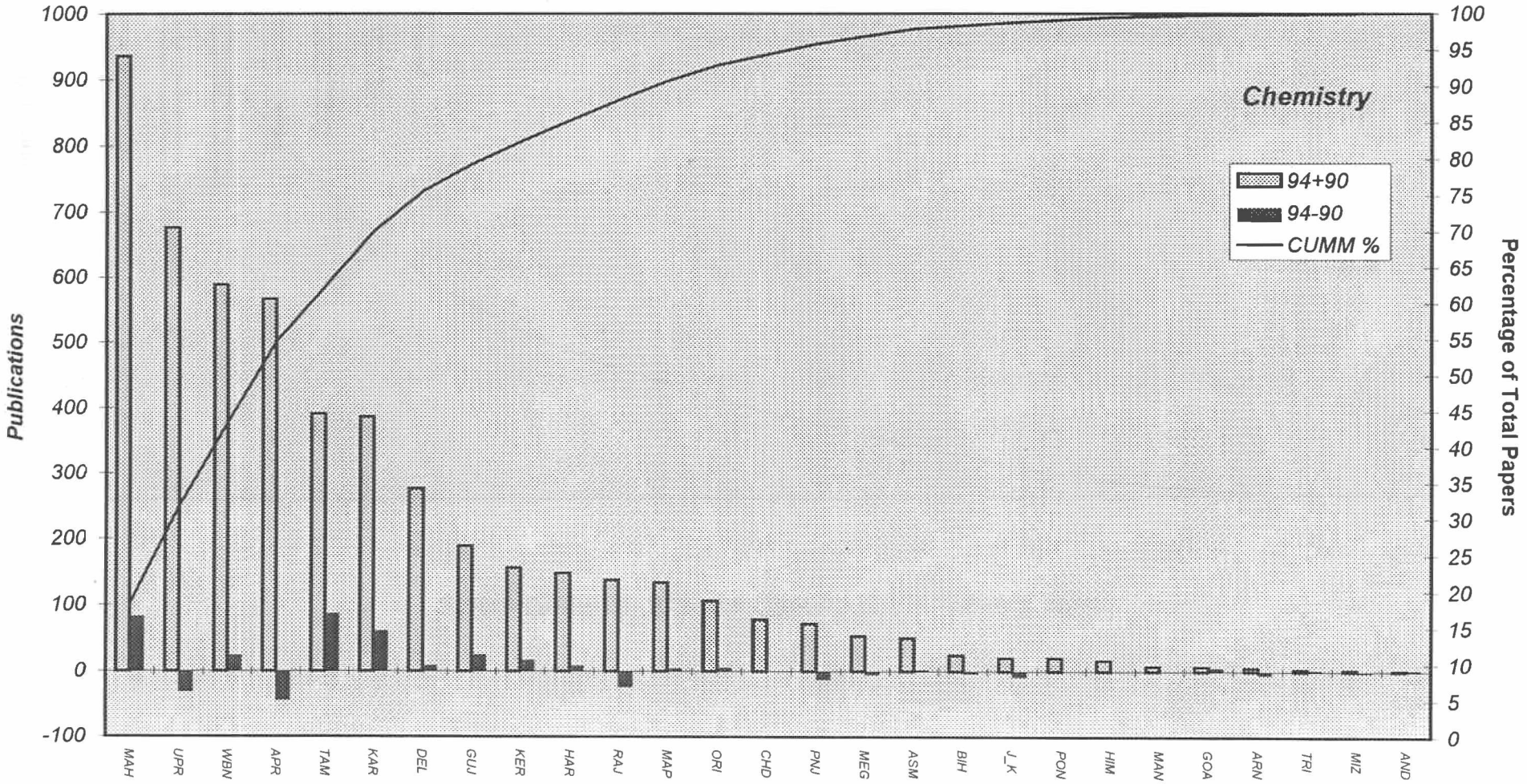
States Output in Science Citation Index : 1990 & 1994



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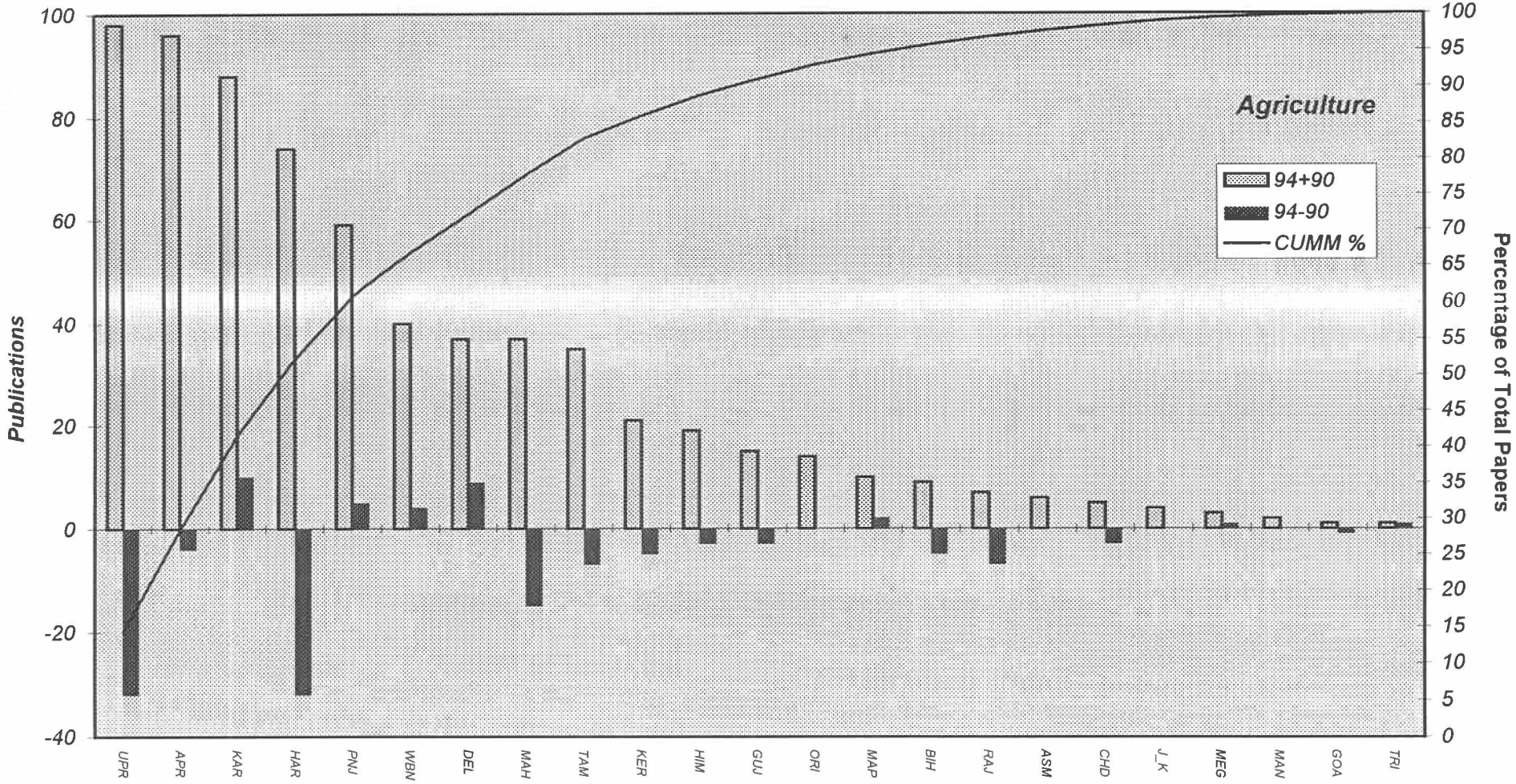
States Output in Science Citation Index : 1990 & 1994



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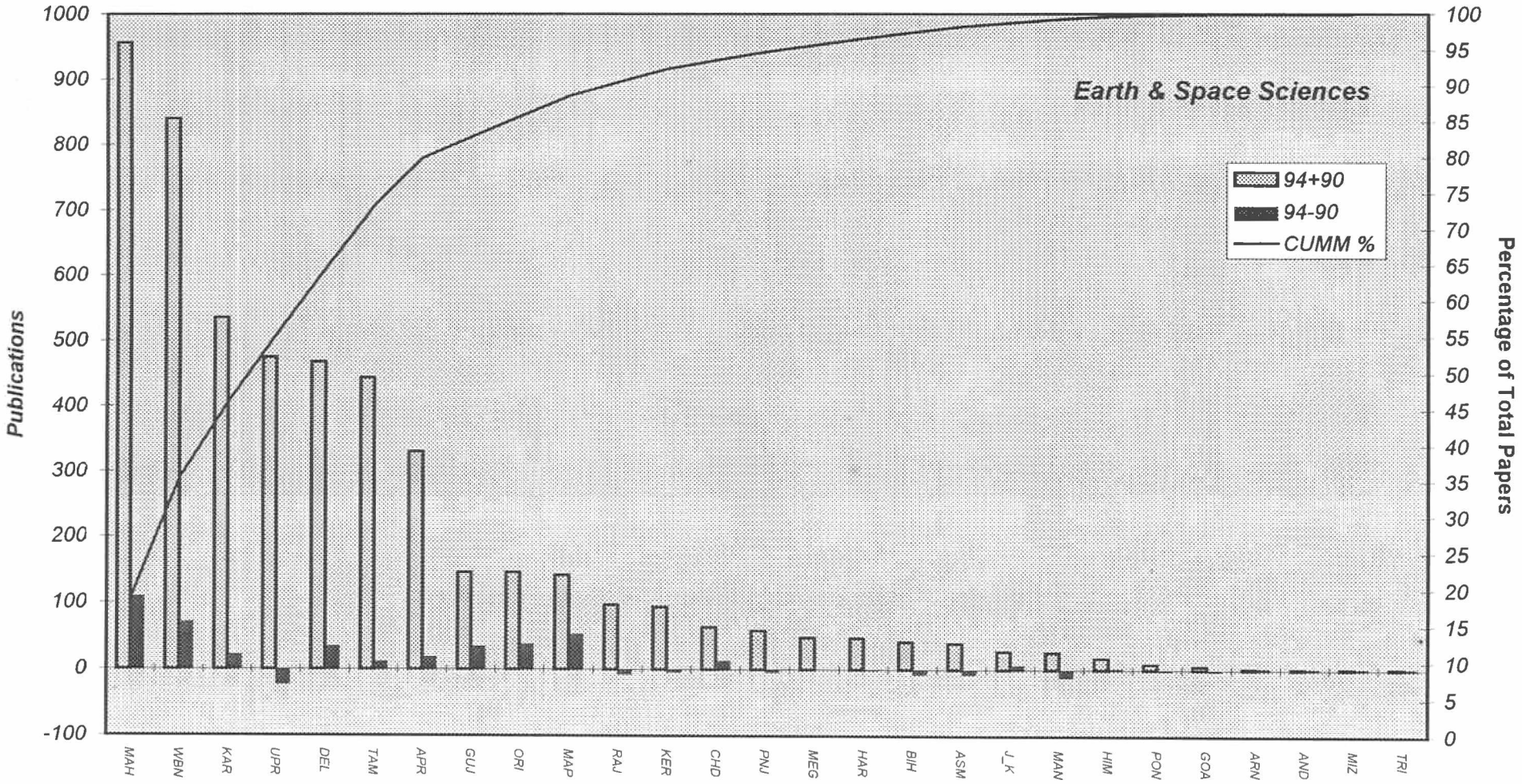
States Output in Science Citation Index : 1990 & 1994



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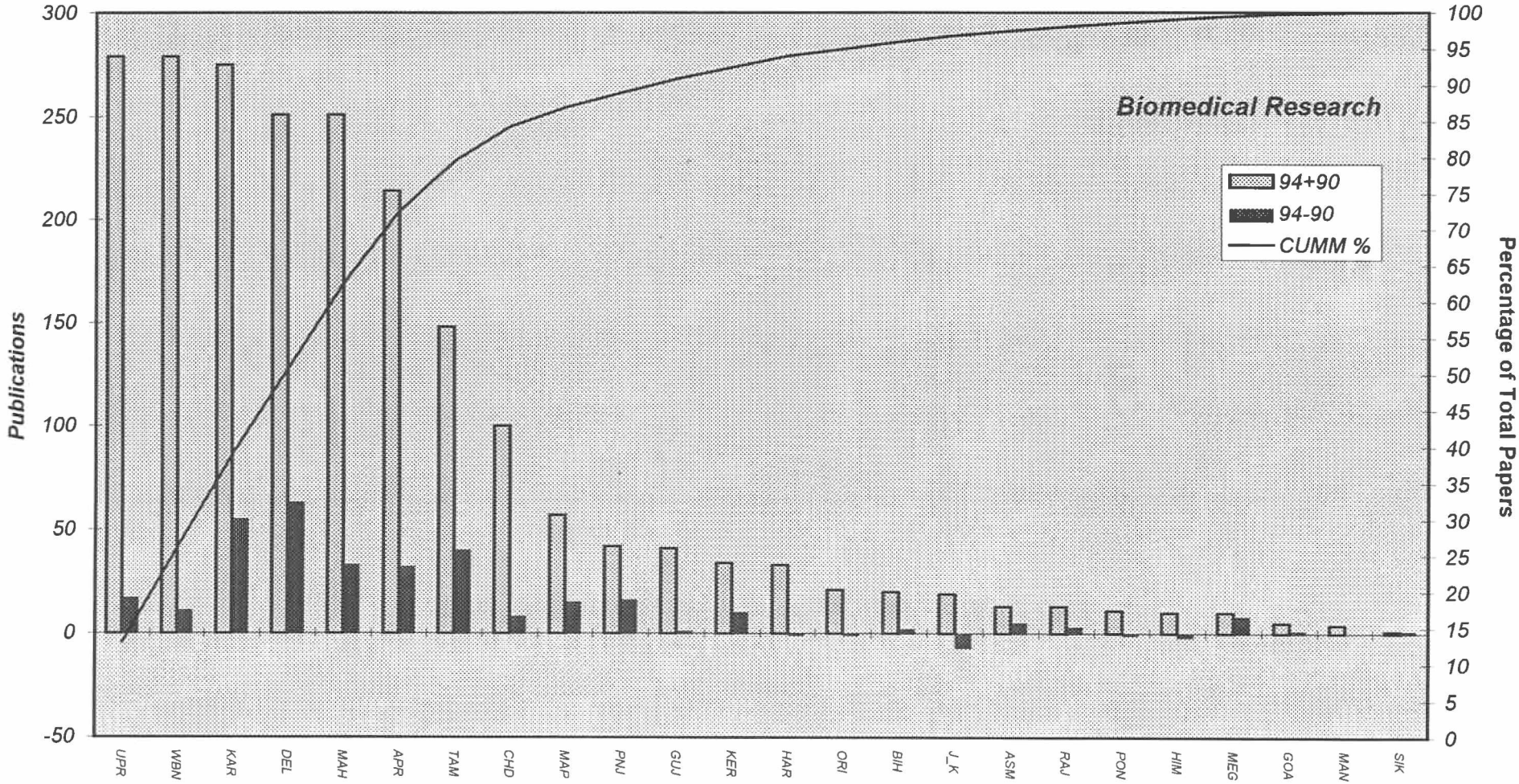
States Output in Science Citation Index : 1990 & 1994



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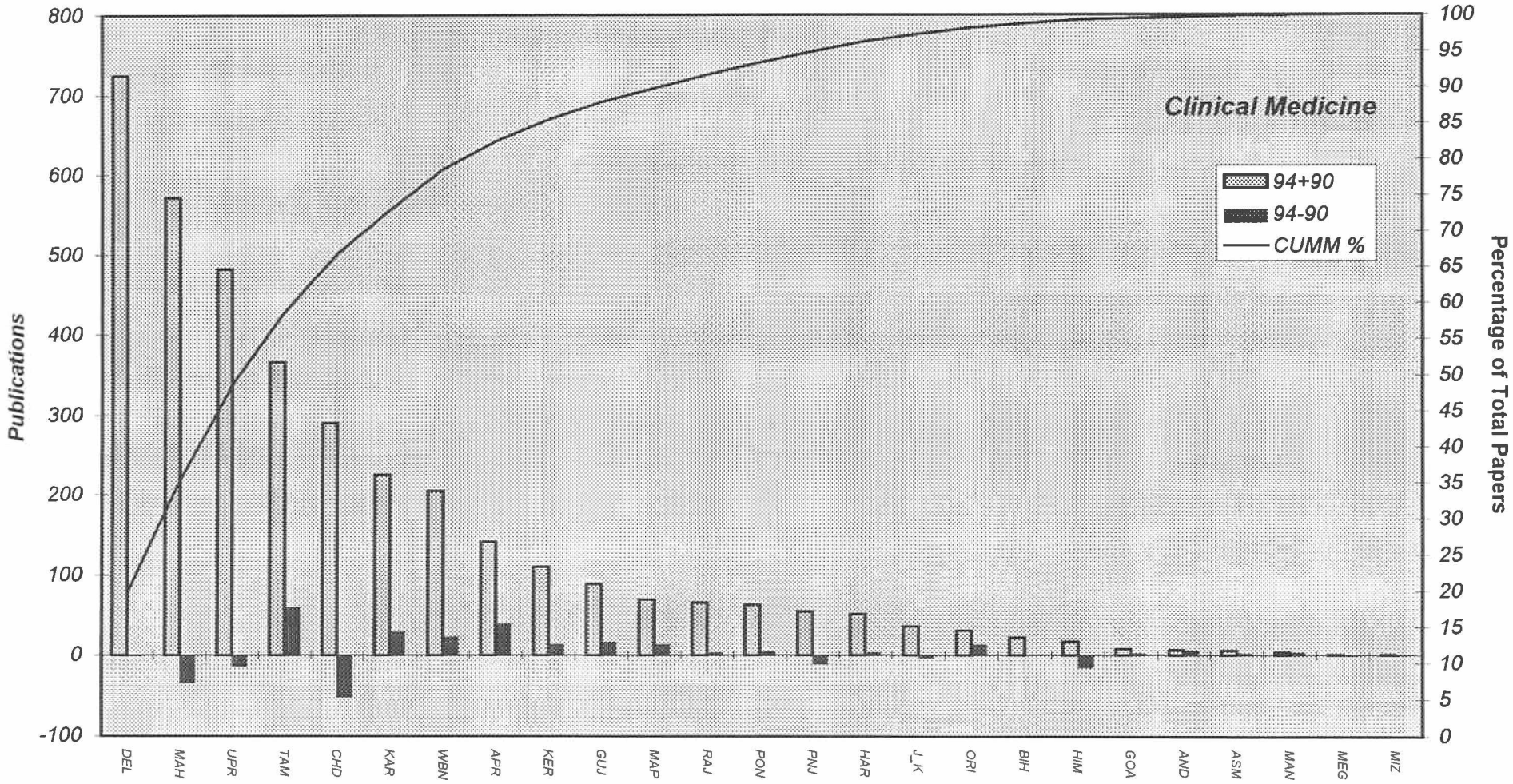
States Output in Science Citation Index : 1990 & 1994



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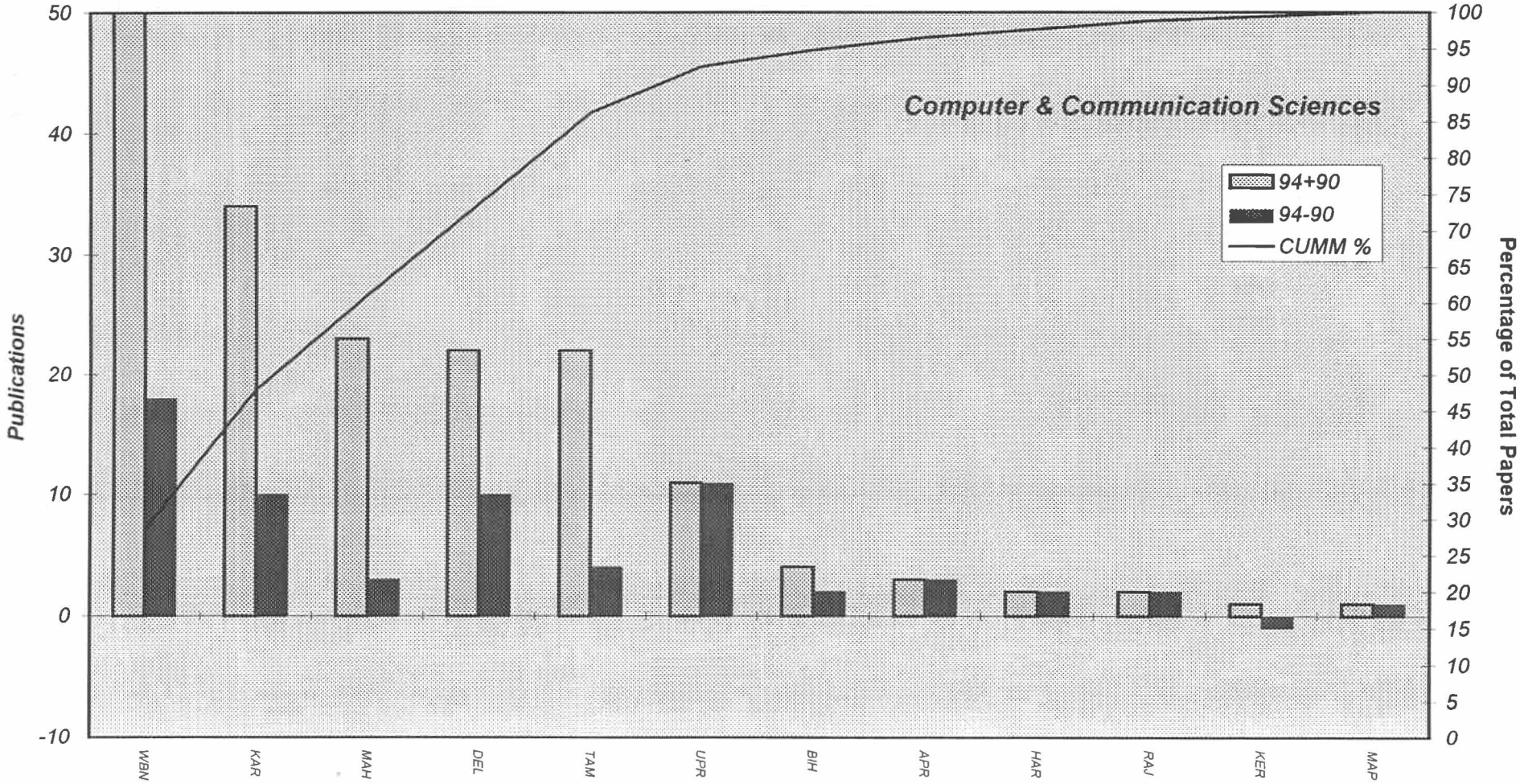
States Output in Science Citation Index : 1990 & 1994



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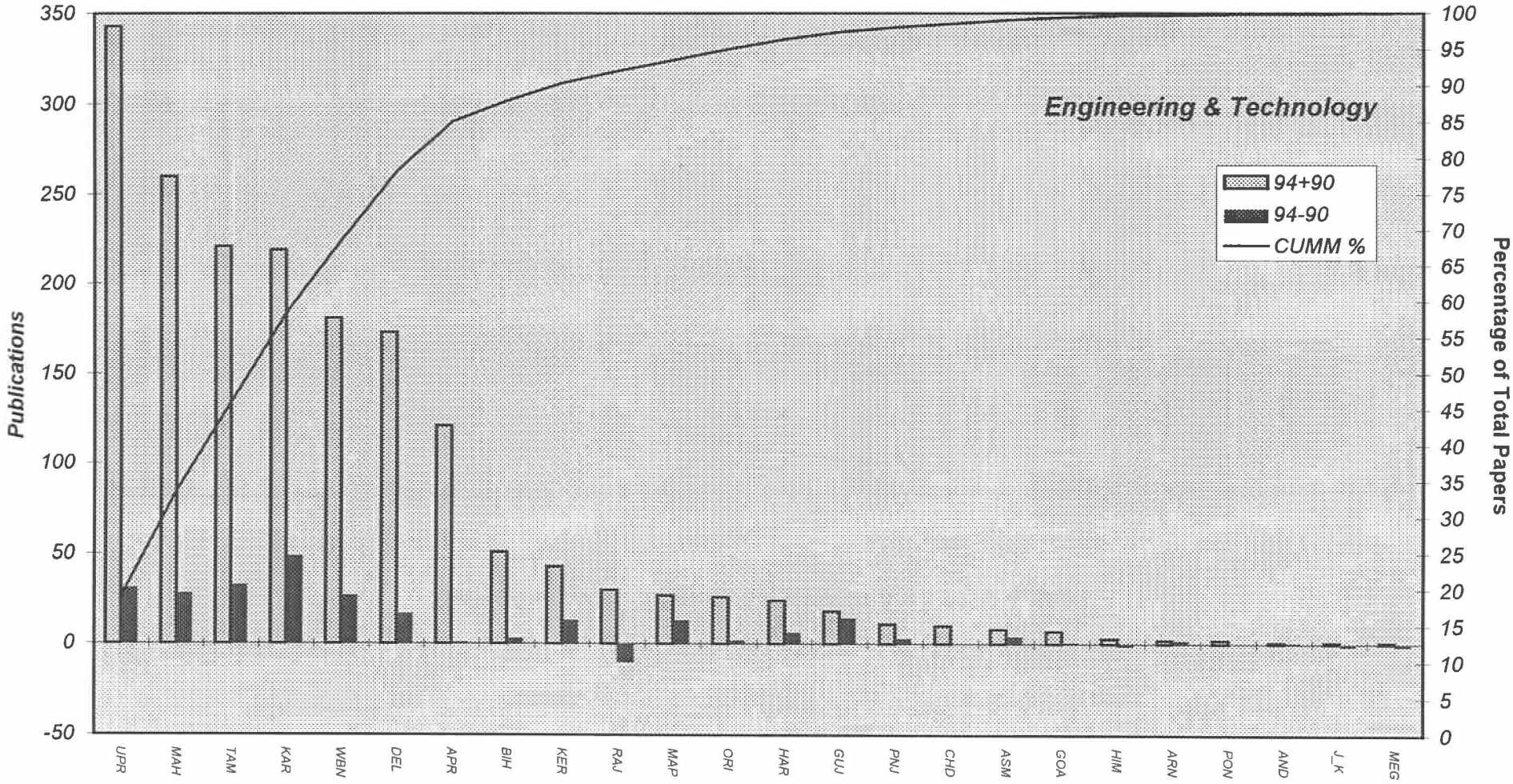
States Output in Science Citation Index : 1990 & 1994



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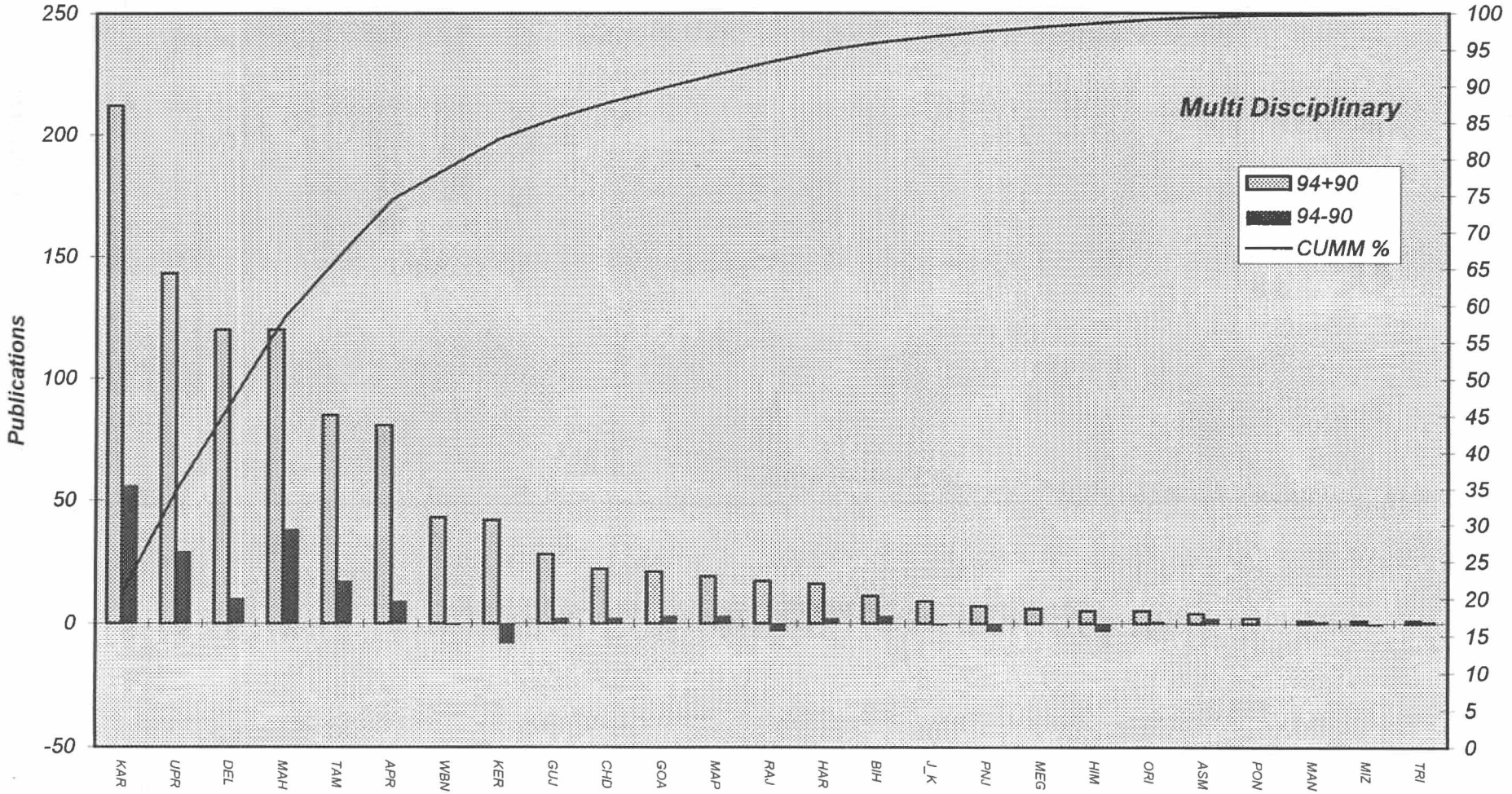
States Output in Science Citation Index : 1990 & 1994



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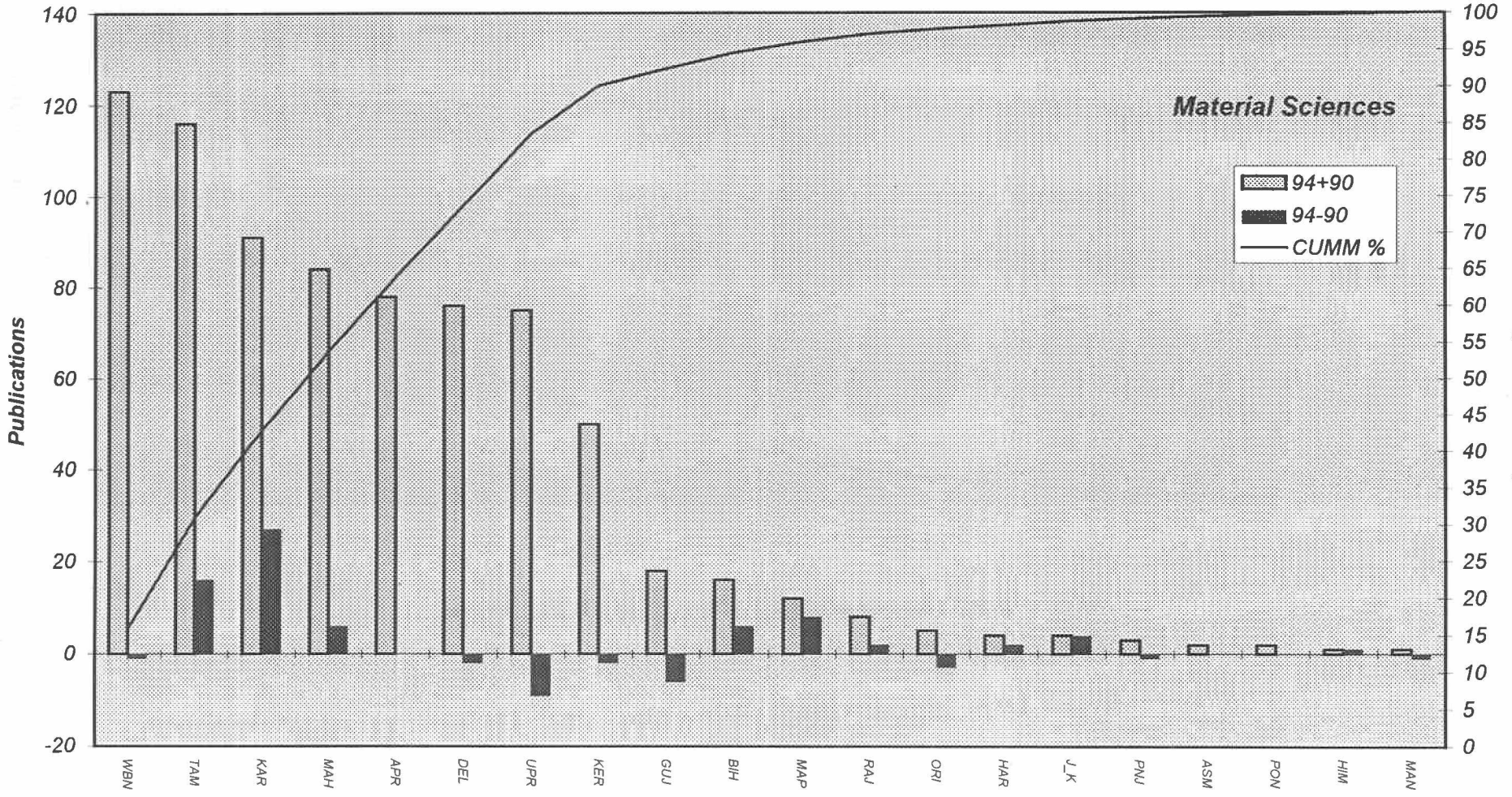
States Output in Science Citation Index : 1990 & 1994



7.8 Research Profiles of the States

Individual state profiles have been created from an analysis of publications from the states, featuring number of papers, average impact, activity and visibility indices in different disciplines; extent of foreign and interstate collaboration, and number of listed addresses (institutions) in the state, etc.

state1

Publication Profile of Indian States

Andhra Pradesh (Population: 66508008)

	1990	1994
No. of papers	900	993
National Rank	6	7
% of Total	8.44	8.13
Average Impact Factor	1.2	1.48
Internationally co-authored papers	84 (9.3%)	162 (16.3%)
Interstate co-authored papers	65 (7.2%)	132 (13.3%)
No. of collaborating states	19	17
No. of Institutional Addresses		138

Publication in Major Disciplines:

Disciplines	1990	1994	Avg_IF '94	Nat Avg_IF '94
Mathematics	13	4	0.50	0.52
Physics	156	174	1.44	1.61
Chemistry	306	261	1.68	1.26
Earth & Space Sciences	42	65	0.82	0.81
Biology	56	82	1.69	1.43
Agriculture	50	46	0.70	0.68
Biomedical Research	91	123	1.67	1.58
Material Science	39	39	0.82	0.79
Engg & Technology	60	61	0.64	0.59
Computer & Comm Sci	-	3	1.01	0.80
Clinical Medicine	51	90	2.66	1.92
Multi-Disciplinary	36	45	0.82	0.81
Total	**900**	**993**	**1.48**	**1.33**

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
Agriculture	Biology	Maths
Biology	Agriculture	Chemistry
Earth & Space Sciences	Comp & Comm Sci	Engg & Technology

High Visibility	Growing Visibility	Declining Visibility
Biology	Biology	Maths
Agriculture	Clinical Medicine	Multi-Disciplinary
Chemistry	Comp & Comm Sci	Engg & Technology
		Chemistry

state1

Publication Profile of Indian States

Arunachal Pradesh (Population: 864558)

	1990	1994
No. of papers	6	4
National Rank	26	25
% of Total	0.06	0.03
Average Impact Factor	0.68	1.99
Internationally co-authored papers	-	-
Interstate co-authored papers	1 (16.7%)	2 (50.0%)
No. of collaborating states	1	4
No. of Institutional Addresses		4

Publication in Major Disciplines:

Disciplines	1990	1994	Avg_IF '94	Nat Avg_IF '94 '94'94
Mathematics	-	-	-	0.52
Physics	-	2	3.23	1.61
Chemistry	5	-	-	1.26
Earth & Space Sciences	-	-	-	0.81
Biology	1		-	1.43
Agriculture	-	-	-	0.68
Biomedical Research	-	-	-	1.58
Material Science	-	-	-	0.79
Engg & Technology	-	2	0.74	0.59
Computer & Comm Sci	-	-	-	0.80
Clinical Medicine	-	-	-	1.92
Multi-Disciplinary	-	-	-	0.81
Total	**6**	**4**	**1.99**	**1.33**

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
Engg & Technology	Engg & Technology	Agriculture
Physics	Physics	Biology

High Visibility	Growing Visibility	Declining Visibility
Engg & Technology	Engg & Technology	Agriculture
Physics	Physics	Biology

state1

Publication Profile of Indian States

Andaman & Nicobar (Population: 280661)

	1990	1994
No. of papers		14
National Rank		24
% of Total		
Average Impact Factor		0.59
Internationally co-authored papers		1
Interstate co-authored papers		2
No. of collaborating states		2
No. of Institutional Addresses		4

Publication in Major Disciplines:

Disciplines	1990	1994	Avg_IF '94	Nat Avg_IF '94
Mathematics				0.52
Physics		1	0.57	1.61
Chemistry		1	2.28	1.26
Earth & Space Sciences		2	0.37	0.81
Biology		2	1.11	1.43
Agriculture				0.68
Biomedical Research				1.58
Material Science				0.79
Engg & Technology		1	0.15	0.59
Computer & Comm Sci				0.80
Clinical Medicine		7	0.32	1.92
Multi-Disciplinary				0.81
Total		**14**	**0.59**	**1.33**

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
High Visibillty	**Growing Visibility**	**Declining Visibility**

state1

Publication Profile of Indian States

Assam (Population: 22294562)

	1990	1994
No. of papers	65	77
National Rank	18	21
% of Total	0.63	0.61
Average Impact Factor	1.01	0.71
Internationally co-authored papers	4 (6.2%)	6 (7.8%)
Interstate co-authored papers	5 (7.7%)	16 (20.8%)
No. of collaborating states	5	17
No. of Institutional Addresses		20

Publication in Major Disciplines:

Disciplines	1990	1994	Avg_IF '94	Nat Avg_IF '94
Mathematics	-	2	0.14	0.52
Physics	23	16	0.64	1.61
Chemistry	24	26	0.64	1.26
Earth & Space Sciences	2	3	0.57	0.81
Biology	3	4	1.07	1.43
Agriculture	3	3	0.84	0.68
Biomedical Research	4	9	0.71	1.58
Material Science	1	1	0.72	0.79
Engg & Technology	2	6	0.71	0.59
Computer & Comm Sci	-	-	-	0.80
Clinical Medicine	2	4	1.63	1.92
Multi-Disciplinary	1	3	0.27	0.81
Total	**65**	**77**	**0.71**	**1.33**

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
Physics	Maths	Physics
Biology	Chemistry	Material Sciences
Material Sciences	Engg & Technology	Biology

High Visibility	Growing Visibility	Declining Visibility
Biology	Agriculture	Physics
Physics	Engg & Technology	Material Science
Material Science	Earth & Space Sciences	Biology

state1

Publication Profile of Indian States

Bihar (Population: 86374465)

	1990	1994
No. of papers	123	119
National Rank	16	16
% of Total	1.15	0.97
Average Impact Factor	0.8	0.97
Internationally co-authored papers	11 (8.9%)	12 (10.1%)
Interstate co-authored papers	30 (24.4%)	37 (31.1%)
No. of collaborating states	11	18
No. of Institutional Addresses		64

Publication in Major Disciplines:

Disciplines	1990	1994	Avg_IF '94	Nat Avg_IF '94
Mathematics	-	1	0.85	0.52
Physics	24	17	1.05	1.61
Chemistry	14	10	1.47	1.26
Earth & Space Sciences	14	12	0.21	0.81
Biology	10	7	0.86	1.43
Agriculture	7	2	1.10	0.68
Biomedical Research	9	11	1.11	1.58
Material Science	5	11	0.78	0.79
Engg & Technology	24	27	0.51	0.59
Computer & Comm Sci	1	3	1.38	0.80
Clinical Medicine	11	11	2.82	1.92
Multi-Disciplinary	4	7	0.27	0.81
Total	**123**	**119**	**0.97**	**1.33**

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
Engg & Technology	Earth & Space Sciences	Clinical Medicine
Material Sciences	Engg & Technology	Physics
Comp & Comm Sci	Material Sciences	Chemistry

High Visibility	Growing Visibility	Declining Visibility
Comp & Comm Sci	Comp & Comm Sci	Physics
Material Sciences	Material Sciences	Clinical Medicine
Engg & Technology	Engg & Technology	Chemistry

state1

Publication Profile of Indian States

Chandigarh

	1990	1994
No. of papers	316	281
National Rank	8	11
% of Total	2.96	2.3
Average Impact Factor	1.3	1.59
Internationally co-authored papers	22 (7.0%)	36 (12.8%)
Interstate co-authored papers	31 (9.8%)	49 (6.8%)
No. of collaborating states	11	19

Publication in Major Disciplines:

Disciplines	1990	1994	Avg_IF '94	Nat Avg_IF '94
Mathematics	3	3	0.37	0.52
Physics	25	38	2.12	1.61
Chemistry	39	39	1.21	1.26
Earth & Space Sciences	5	7	0.44	0.81
Biology	8	3	5.39	1.43
Agriculture	4	1	1.34	0.68
Biomedical Research	46	54	1.18	1.58
Material Science	-	-	-	0.79
Engg & Technology	5	5	0.50	0.59
Computer & Comm Sci	-	-	-	0.80
Clinical Medicine	171	119	1.91	1.92
Multi-Disciplinary	10	12	0.25	0.81
Total	***316***	***281***	***1.59***	***1.33***

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
Engg & Technology	Material Sciences	Clinical Medicine
Material Sciences	Comp & Comm Sci	Biomedical Research
Comp & Comm Sci	Engg & Technology	Chemistry

High Visibility	Growing Visibility	Declining Visibility
Comp & Comm Sci	Comp & Comm Sci	Clinical Medicine
Material Sciences	Material Sciences	Multi-Disciplinary
Engg & Technology	Engg & Technology	Biomedical Research

state1

Publication Profile of Indian States

Delhi (Population : 9420644)

	1990	1994
No. of papers	1107	1312
National Rank	4	4
% of Total	10.38	10.75
Average Impact Factor	1.32	1.54
Internationally co-authored papers	110 (9.9%)	194 (14.8%)
Interstate co-authored papers	116 (10.5%)	191 (14.6%)
No. of collaborating states	19	22
No. of Institutional Addresses		140

Publication in Major Disciplines:

Disciplines	1990	1994	Avg_IF '94	Nat Avg_IF '94
Mathematics	19	39	0.50	0.52
Physics	217	251	1.53	1.61
Chemistry	134	142	1.20	1.26
Earth & Space Sciences	38	56	0.73	0.81
Biology	50	69	2.45	1.43
Agriculture	14	23	0.89	0.68
Biomedical Research	94	157	1.85	1.58
Material Science	39	37	0.89	0.79
Engg & Technology	78	95	0.53	0.59
Computer & Comm Sci	6	16	0.65	0.80
Clinical Medicine	363	362	2.06	1.92
Multi-Disciplinary	55	65	1.42	0.81
Total	***1107***	***1312***	***1.54***	***1.33***

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
Clinical Medicine	Maths	Multi-Disciplinary
Maths	Agriculture	Material Sciences
Comp & Comm Sci	Biology	Clinical Medicine

High Visibility	Growing Visibility	Declining Visibility
Clinical Medicine	Multi-Disciplinary	Clinical Medicine
Biology	Maths	Engg & Technology
Multi-Disciplinary	Biology	Earth & Space Sciences

state1

Publication Profile of Indian States

Goa (Population : 1169793)

	1990	1994
No. of papers	70	79
National Rank	19	17
% of Total	0.66	0.65
Average Impact Factor	1.2	1.05
Internationally co-authored papers	5 (7.1%)	17 (21.5%)
Interstate co-authored papers	13 (18.6%)	14 (17.7%)
No. of collaborating states	6	16
No. of Institutional Addresses		7

Publication in Major Disciplines:

Disciplines	1990	1994	Avg_IF '94	Nat Avg_IF '94
Mathematics	-	2	0.67	0.52
Physics	4	1	0.40	1.61
Chemistry	1	6	0.81	1.26
Earth & Space Sciences	41	34	1.17	0.81
Biology	6	12	0.68	1.43
Agriculture	1	-	-	0.68
Biomedical Research	2	3	3.39	1.58
Material Science	-	-	-	0.79
Engg & Technology	3	4	0.54	0.59
Computer & Comm Sci	-	-	-	0.80
Clinical Medicine	3	5	2.66	1.92
Multi-Disciplinary	9	12	0.27	0.81
Total	**70**	**79**	**1.05**	**1.33**

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
Earth & Space Sciences	Maths	Earth & Space Sciences
Multi-Disciplinary	Biology	Agriculture
Biology	Chemistry	Physics

High Visibility	Growing Visibility	Declining Visibility
Earth & Space Sciences	Maths	Multi-Disciplinary
Maths	Earth & Space Sciences	Agriculture
Biology	Biomedical Research	Physics

state1

Publication Profile of Indian States

Gujarat (Population : 41309582)

	1990	1994
No. of papers	283	392
National Rank	10	8
% of Total	2.65	3.21
Average Impact Factor	1.2	1.27
Internationally co-authored papers	33 (11.7%)	56 (14.3%)
Interstate co-authored papers	36	69
No. of collaborating states	11	19
No. of Institutional Addresses		70

Publication in Major Disciplines:

Disciplines	90	94	Avg_IF '94	Nat Avg_IF '94
Mathematics	5	2	0.34	0.52
Physics	56	90	1.50	1.61
Chemistry	82	107	1.09	1.26
Earth & Space Sciences	34	66	1.06	0.81
Biology	14	10	0.76	1.43
Agriculture	9	6	0.49	0.68
Biomedical Research	20	21	1.50	1.58
Material Science	12	6	0.51	0.79
Engg & Technology	2	16	0.48	0.59
Computer & Comm Sci	-	-	-	0.80
Clinical Medicine	36	53	2.23	1.92
Multi-Disciplinary	13	15	0.27	0.81
Total	***283***	***392***	***1.27***	***1.33***

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
Earth & Space Sciences	Maths	Earth & Space Sciences
Material Sciences	Material Sciences	Engg & Technology
Chemistry		

High Visibility	Growing Visibility	Declining Visibility
Earth & Space Sciences	Multi-Disciplinary	Clinical Medicine
Multi-Disciplinary	Maths	Engg & Technology

state1

Publication Profile of Indian States

Haryana (Population : 16463648)

	1990	1994
No. of papers	232	229
National Rank	12	12
% of Total	2.17	1.88
Average Impact Factor	0.79	0.87
Internationally co-authored papers	25 (10.8%)	16 (7.0%)
Interstate co-authored papers	25 (10.8%)	38 (16.6%)
No. of collaborating states	12	13
No. of Institutional Addresses		27

Publication in Major Disciplines:

Disciplines	1990	1994	Avg_IF '94	Nat Avg_IF '94
Mathematics	1	-	-	0.52
Physics	24	23	0.93	1.61
Chemistry	70	78	0.69	1.26
Earth & Space Sciences	6	9	0.62	0.81
Biology	20	25	0.63	1.43
Agriculture	53	21	0.77	0.68
Biomedical Research	17	16	1.40	1.58
Material Science	1	3	0.87	0.79
Engg & Technology	9	15	0.36	0.59
Computer & Comm Sci	-	2	0.27	0.80
Clinical Medicine	24	28	1.85	1.92
Multi-Disciplinary	7	9	0.33	0.81
Total	**232**	**229**	**0.87**	**1.33**

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
Agriculture	Comp & Comm Sci	Agriculture
Biology	Biology	Maths
Chemistry	Material Sciences	Biomedical Research

High Visibility	Growing Visibility	Declining Visibility
Agriculture	Clinical Medicine	Agriculture
Biology	Comp & Comm Sci	Biology
Chemistry	Material Sciences	Chemistry

state1

Publication Profile of Indian States

Himachal Pradesh (Population : 5170877)

	1990	1994
No. of papers	66	47
National Rank	20	22
% of Total	0.62	0.38
Average Impact Factor	1.03	0.78
Internationally co-authored papers	3 (4.5%)	5 (10.6%)
Interstate co-authored papers	7 (10.6%)	12 (25.5%)
No. of collaborating states	6	7
No. of Institutional Addresses		17

Publication in Major Disciplines:

Disciplines	1990	1994	Avg_IF '94	Nat Avg_IF '94
Mathematics	1	2	0.34	0.52
Physics	8	9	1.14	1.61
Chemistry	8	8	0.87	1.26
Earth & Space Sciences	1	1	0.47	0.81
Biology	9	11	0.74	1.43
Agriculture	11	8	0.64	0.68
Biomedical Research	6	4	0.90	1.58
Material Science	0	1	0.74	0.79
Engg & Technology	2	1	0.63	0.59
Computer & Comm Sci	-	-	-	0.80
Clinical Medicine	16	1	-	1.92
Multi-Disciplinary	4	1	0.27	0.81
Total	**66**	**47**	**0.78**	**1.33**

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
Agriculture	Biology	Clinical Medicine
Biology	Agriculture	Multi-Disciplinary
Maths	Maths	Biomedical Research

High Visibility	Growing Visibility	Declining Visibility
Agriculture	Agriculture	Clinical Medicine
Biology	Biology	Chemistry
Maths	Maths	Engg & Technology

state1

Publication Profile of Indian States

Jammu & Kashmir (Population : 7718700)

	1990	1994
No. of papers	81	68
National Rank	17	20
% of Total	0.76	0.56
Average Impact Factor	1.33	0.88
Internationally co-authored papers	14 (17.3%)	17 (25.0%)
Interstate co-authored papers	13 (16.0%)	23 (33.8%)
No. of collaborating states	7	17
No. of Institutional Addresses		21

Publication in Major Disciplines:

Disciplines	90	94	Avg_IF '94	Nat Avg_IF '94
Mathematics	-	-	-	0.52
Physics	10	17	1.05	1.61
Chemistry	14	6	0.36	1.26
Earth & Space Sciences	2	9	0.44	0.81
Biology	14	4	1.10	1.43
Agriculture	2	2	0.32	0.68
Biomedical Research	13	6	1.40	1.58
Material Science	-	4	0.78	0.79
Engg & Technology	1	-	-	0.59
Computer & Comm Sci	-	-	-	0.80
Clinical Medicine	20	16	1.07	1.92
Multi-Disciplinary	5	4	0.49	0.81
Total	***81.00***	***68.00***	***0.88***	***1.33***

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
Earth & Space Sciences	Earth & Space Sciences	Biology
Material Sciences	Material Sciences	Biomedical Research
Clinical Medicine	Physics	Chemistry

High Visibility	Growing Visibility	Declining Visibility
Material Sciences	Material Sciences	Biology
Earth & Space Sciences	Earth & Space Sciences	Chemistry
Clinical Medicine	Multi-Disciplinary	Clinical Medicine

state1

Publication Profile of Indian States

Karnataka (Population : 44977201)

	1990	1994
No. of papers	956	1275
National Rank	5	5
% of Total	8.96	10.44
Average Impact Factor	1.27	1.47
Internationally co-authored papers	139 (14.5%)	193 (51.1%)
Interstate co-authored papers	78 (8.2%)	158 (12.4%)
No. of collaborating states	14	19
No. of Institutional Addresses		144

Publication in Major Disciplines:

Disciplines	1990	1994	Avg_IF '94	Nat Avg_IF '94
Mathematics	27	17	0.46	0.52
Physics	257	278	1.98	1.61
Chemistry	163	223	1.51	1.26
Earth & Space Sciences	18	31	0.89	0.81
Biology	37	36	1.18	1.43
Agriculture	39	49	0.74	0.68
Biomedical Research	110	165	1.96	1.58
Material Science	32	59	1.01	0.79
Engg & Technology	85	134	0.66	0.59
Computer & Comm Sci	12	22	0.84	0.80
Clinical Medicine	98	127	2.34	1.92
Multi-Disciplinary	78	134	0.62	0.81
Total	*956*	*1275*	*1.47*	*1.33*

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
Multi-Disciplinary	Agriculture	Maths
Comp & Comm Sci	Material Sciences	Comp & Comm Sci
Agriculture	Multi-Disciplinary	Biology

High Visibility	Growing Visibility	Declining Visibility
Comp & Comm Sci	Multi-Disciplinary	Comp & Comm Sci
Material Sciences	Material Sciences	Maths
Agriculture	Agriculture	Physics

state1

Publication Profile of Indian States

Kerala (Population : 29098518)

	1990	1994
No. of papers	300	340
National Rank	9	9
% of Total	2.81	2.79
Average Impact Factor	0.96	1.12
Internationally co-authored papers	26 (8.7%)	37 (10.9%)
Interstate co-authored papers	31 (10.3%)	54 (15.9%)
No. of collaborating states	12	17
No. of Institutional Addresses		66

Publication in Major Disciplines:

Disciplines	1990	1994	Avg_IF '94	Nat Avg_IF '94
Mathematics	2	4	0.61	0.52
Physics	49	45	1.14	1.61
Chemistry	70	86	1.20	1.26
Earth & Space Sciences	15	25	1.00	0.81
Biology	24	19	0.76	1.43
Agriculture	13	8	0.76	0.68
Biomedical Research	12	22	1.51	1.58
Material Science	26	24	0.80	0.79
Engg & Technology	15	28	0.71	0.59
Computer & Comm Sci	1	-	-	0.80
Clinical Medicine	48	62	1.62	1.92
Multi-Disciplinary	25	17	0.27	0.81
Total	**300**	**340**	**1.12**	**1.33**

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
Material Sciences	Maths	Multi-Disciplinary
Earth & Space Sciences	Earth & Space Sciences	Comp & Comm Sci
Chemistry	Engg & Technology	Material Sciences

High Visibility	Growing Visibility	Declining Visibility
Material Sciences	Engg & Technology	Material Sciences
Earth & Space Sciences	Maths	Biology
Engg & Technology	Earth & Space Sciences	Comp & Comm Sci

state1

Publication Profile of Indian States

Maharashtra (Population : 78937187)

	1990	1994
No. of papers	1607	1904
National Rank	1	1
% of Total	15.06	15.6
Average Impact Factor	1.55	1.57
Internationally co-authored papers	183 (11.4%)	309 (16.2%)
Interstate co-authored papers	115 (7.2%)	204 (10.7%)
No. of collaborating states	10	13
No. of Institutional Addresses		262

Publication in Major Disciplines:

Disciplines	1990	1994	Avg_IF '94	Nat Avg_IF '94
Mathematics	41	43	0.53	0.52
Physics	424	533	1.92	1.61
Chemistry	427	509	1.51	1.26
Earth & Space Sciences	39	71	0.82	0.81
Biology	32	45	1.18	1.43
Agriculture	26	11	0.64	0.68
Biomedical Research	109	142	2.01	1.58
Material Science	39	45	0.76	0.79
Engg & Technology	116	144	0.69	0.59
Computer & Comm Sci	10	13	0.91	0.80
Clinical Medicine	303	269	1.97	1.92
Multi-Disciplinary	41	79	1.23	0.81
Total	**1607**	**1904**	**1.57**	**1.33**

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
Maths	Multi-Disciplinary	Comp & Comm Sci
Physics	Earth & Space Sciences	Agriculture
Chemistry	Biology	Maths

High Visibility	Growing Visibility	Declining Visibility
Physics	Earth & Space Sciences	Clinical Medicine
Chemistry	Chemistry	Agriculture
Multi-Disciplinary	Biomedical Research	Multi-Disciplinary

state1

Publication Profile of Indian States

Manipur (Population : 1837149)

	1990	1994
No. of papers	29	21
National Rank	23	23
% of Total	0.27	0.17
Average Impact Factor	0.79	0.6
Internationally co-authored papers	2 (6.9%)	4 (19.0%)
Interstate co-authored papers	3 (10.3%)	11 (52.4%)
No. of collaborating states	16	18
No. of Institutional Addresses		15

Publication in Major Disciplines:

Disciplines	1990	1994	Avg_IF '94	Nat Avg_IF '94 '94'94
Mathematics	-	-	-	0.52
Physics	19	7	0.45	1.61
Chemistry	4	4	0.57	1.26
Earth & Space Sciences	-	2	0.60	0.81
Biology	2	-	-	1.43
Agriculture	1	1	1.00	0.68
Biomedical Research	2	2	0.99	1.58
Material Science	1	-	-	0.79
Engg & Technology	-	-	-	0.59
Computer & Comm Sci	-	-	-	0.80
Clinical Medicine	-	4	0.68	1.92
Multi-Disciplinary	-	1	0.27	0.81
Total	**29**	**21**	**0.60**	**1.33**

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
Earth & Space Sciences	Earth & Space Sciences	Physics
Agriculture	Clinical Medicine	Biology
Physics	Agriculture	Material Sciences

High Visibility	Growing Visibility	Declining Visibility
Agriculture	Agriculture	Biology
Earth & Space Sciences	Earth & Space Sciences	Material Sciences
Biomedical Research	Clinical Medicine	Physics

state1

Publication Profile of Indian States

Madhya Pradesh (Population : 66181000)

	1990	1994
No. of papers	202	320
National Rank	13	10
% of Total	1.89	2.62
Average Impact Factor	0.86	1.1
Internationally co-authored papers	13 (6.4%)	29 (9.1%)
Interstate co-authored papers	29 (14.4%)	70 (21.9%)
No. of collaborating states	4	4
No. of Institutional Addresses		76

Publication in Major Disciplines:

Disciplines	90	94	Avg_IF '94	Nat Avg_IF '94
Mathematics	1	3	0.54	0.52
Physics	45	97	1.39	1.61
Chemistry	65	69	1.01	1.26
Earth & Space Sciences	9	11	0.49	0.81
Biology	12	14	1.88	1.43
Agriculture	4	6	0.55	0.68
Biomedical Research	21	36	1.36	1.58
Material Science	2	10	0.65	0.79
Engg & Technology	7	20	0.39	0.59
Computer & Comm Sci	-	1	1.80	0.80
Clinical Medicine	28	42	1.02	1.92
Multi-Disciplinary	8	11	0.27	0.81
Total	**202**	**320**	**1.10**	**1.33**

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
Physics	Material Sciences	Chemistry
Biomedical Research	Physics	Earth & Space Sciences
Chemistry	Comp & Comm Sci	Multi-Disciplinary

High Visibility	Growing Visibility	Declining Visibility
Physics	Comp & Comm Sci	Biomedical Research
Biology	Material Sciences	Earth & Space Sciences
Biomedical Research	Physics	Biomedical Research

state1

Publication Profile of Indian States

Meghalaya *(Population : 1774778)*

	1990	*1994*
No. of papers	75	71
National Rank	18	19
% of Total	0.7	0.58
Average Impact Factor	1.2	1
Internationally co-authored papers	5 (6.7%)	13 (18.3%)
Interstate co-authored papers	6 (8.0%)	9 (12.7%)
No. of collaborating states	3	6
No. of Institutional Addresses		11

Publication in Major Disciplines:

Disciplines	*90*	*94*	*Avg_IF '94*	*Nat Avg_IF '94*
Mathematics	1	-	-	0.52
Physics	24	24	1.07	1.61
Chemistry	29	24	1.16	1.26
Earth & Space Sciences	2	2	0.64	0.81
Biology	12	7	0.82	1.43
Agriculture	1	2	0.27	0.68
Biomedical Research	1	9	0.99	1.58
Material Science	-	-	-	0.79
Engg & Technology	1	-	-	0.59
Computer & Comm Sci	-	-	-	0.80
Clinical Medicine	1	-	-	1.92
Multi-Disciplinary	3	3	0.27	0.81
Total	***75***	***71***	***1.00***	***1.33***

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	***Growing Activity***	***Declining Activity***
Biology	Biomedical Research	Biology
Chemistry	Agriculture	Maths
Physics	Physics	Engg & Technology

High Visibility	***Growing Visibility***	***Declining Visibility***
Chemistry	Biomedical Research	Biology
Biology	Physics	Chemistry
Physics	Agriculture	Maths

state1

Publication Profile of Indian States

Mizoram (Population : 689756)

	1990	1994
No. of papers	7	10
National Rank	26	27
% of Total	0.02	0.02
Average Impact Factor	0.34	0.38
Internationally co-authored papers	-	1 (10.0%)
Interstate co-authored papers	1 (14.3%)	1 (10.0%)
No. of collaborating states	1	2
No. of Institutional Addresses		2

Publication in Major Disciplines:

Disciplines	90	94	Avg_IF '94	Nat Avg_IF '94
Mathematics	-	-	-	0.52
Physics	-	1	0.76	1.61
Chemistry	2	-	-	1.26
Earth & Space Sciences	-	-	-	0.81
Biology	-	-	-	1.43
Agriculture	-	-	-	0.68
Biomedical Research	-	-	-	1.58
Material Science	-	-	-	0.79
Engg & Technology	-	-	-	0.59
Computer & Comm Sci	-	-	-	0.80
Clinical Medicine	-	1	-	1.92
Multi-Disciplinary	1	-	-	0.81
Total	**3**	**2**	**0.38**	**1.33**

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
High Visibility	**Growing Visibility**	**Declining Visibility**

state1

Publication Profile of Indian States

Orissa (Population : 31659736)

	1990	1994
No. of papers	171	224
National Rank	15	13
% of Total	1.6	1.83
Average Impact Factor	1.2	1.34
Internationally co-authored papers	22 (12.9%)	17 (7.6%)
Interstate co-authored papers	25 (14.6%)	44 (19.6%)
No. of collaborating states	7	18
No. of Institutional Addresses	52	

Publication in Major Disciplines:

Disciplines	1990	1994	Avg_IF '94	Nat Avg_IF '94
Mathematics	1	5	0.45	0.52
Physics	54	92	1.90	1.61
Chemistry	51	56	0.86	1.26
Earth & Space Sciences	6	6	1.08	0.81
Biology	14	8	1.13	1.43
Agriculture	7	7	0.71	0.68
Biomedical Research	11	10	1.03	1.58
Material Science	4	1	0.36	0.79
Engg & Technology	12	14	0.62	0.59
Computer & Comm Sci	-	-	-	0.80
Clinical Medicine	9	22	1.55	1.92
Multi-Disciplinary	2	3	0.26	0.81
Total	**171**	**224**	**1.34**	**1.33**

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
Physics	Maths	Biology
Maths	Physics	Material Sciences
Agriculture	Clinical Medicine	Biomedical Research

High Visibility	Growing Visibility	Declining Visibility
Physics	Maths	Material Sciences
Agriculture	Physics	Biomedical Research
Maths	Agriculture	Biology

state1

Publication Profile of Indian States

Punjab (Population : 20281969)

	1990	1994
No. of papers	178	173
National Rank	14	15
% of Total	1.67	1.42
Average Impact Factor	0.86	0.96
Internationally co-authored papers	12 (6.7%)	10 (5.8%)
Interstate co-authored papers	21 (11.8%)	33 (19.1%)
No. of collaborating states	5	16
No. of Institutional Addresses		46

Publication in Major Disciplines:

Disciplines	1990	1994	Avg_IF '94	Nat Avg_IF '94
Mathematics	3	2	1.58	0.52
Physics	31	27	1.08	1.61
Chemistry	42	30	0.47	1.26
Earth & Space Sciences	1	5	1.83	0.81
Biology	17	16	1.76	1.43
Agriculture	27	32	0.62	0.68
Biomedical Research	13	29	1.02	1.58
Material Science	2	1	0.66	0.79
Engg & Technology	4	7	0.43	0.59
Computer & Comm Sci	-	-	-	0.80
Clinical Medicine	33	22	1.30	1.92
Multi-Disciplinary	5	2	0.27	0.81
Total	**178**	**173**	**0.96**	**1.33**

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
Agriculture	Agriculture	Multi-Disciplinary
Biology	Biomedical Research	
Biomedical Research	Earth & Space Sciences	

High Visibility	Growing Visibility	Declining Visibility
Agriculture	Agriculture	Material Sciences
Biology	Earth & Space Sciences	
Maths		

state1

Publication Profile of Indian States

Pondicherry (Population : 807785)

	1990	1994
No. of papers	59	65
National Rank	22	21
% of Total	0.55	0.53
Average Impact Factor	0.66	1.69
Internationally co-authored papers	4 (6.8%)	13 (20.0%)
Interstate co-authored papers	9 (15.3%)	14 (21.5%)
No. of collaborating states	7	11
No. of Institutional Addresses		10

Publication in Major Disciplines:

Disciplines	1990	1994	Avg_IF '94	Nat Avg_IF '94
Mathematics	1	-	-	0.52
Physics	5	3	0.91	1.61
Chemistry	10	10	1.00	1.26
Earth & Space Sciences	-	4	0.56	0.81
Biology	5	6	0.79	1.43
Agriculture	-	-	-	0.68
Biomedical Research	6	5	1.41	1.58
Material Science	1	1	0.90	0.79
Engg & Technology	1	1	0.69	0.59
Computer & Comm Sci	-	-	-	0.80
Clinical Medicine	29	34	1.64	1.92
Multi-Disciplinary	1	1	25.47	0.81
Total	**59**	**65**	**1.69**	**1.33**

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
Clinical Medicine	Earth & Space Sciences	Maths
Biology	Biology	Biomedical Research
Earth & Space Sciences	Clinical Medicine	

High Visibility	Growing Visibility	Declining Visibility
Multi-Disciplinary	Multi-Disciplinary	Biomedical Research
Clinical Medicine	Earth & Space Sciences	Maths
Biology		Biology

state1

Publication Profile of Indian States

Rajasthan (Population : 44005990)

	1990	1994
No. of papers	234	186
National Rank	11	14
% of Total	2.19	1.52
Average Impact Factor	1.01	1.2
Internationally co-authored papers	24 (10.3%)	27 (14.5%)
Interstate co-authored papers	24 (10.3%)	35 (18.8%)
No. of collaborating states	9	17
No. of Institutional Addresses		62

Publication in Major Disciplines:

Disciplines	1990	1994	Avg_IF '94	Nat Avg_IF '94
Mathematics	3	2	0.60	0.52
Physics	52	45	1.07	1.61
Chemistry	81	57	1.11	1.26
Earth & Space Sciences	6	3	0.88	0.81
Biology	16	12	0.56	1.43
Agriculture	7	-	-	0.68
Biomedical Research	5	8	0.85	1.58
Material Science	3	5	0.80	0.79
Engg & Technology	20	10	0.55	0.59
Computer & Comm Sci	0	2	0.50	0.80
Clinical Medicine	31	35	2.35	1.92
Multi-Disciplinary	10	7	0.34	0.81
Total	***234***	***186***	***1.20***	***1.33***

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
Chemistry	Comp & Comm Sci	Agriculture
Biology	Material Sciences	Engg & Technology
Clinical Medicine	Clinical Medicine	

High Visibility	Growing Visibility	Declining Visibility
Clinical Medicine	Comp & Comm Sci	Biology
Chemistry	Clinical Medicine	Agriculture
Material Sciences	Material Sciences	Engg & Technology

state1

Publication Profile of Indian States

Sikkim	(Population : 406457)	
	1990	1994
No. of papers		
National Rank		
% of Total		
Average Impact Factor		
Internationally co-authored papers		
Interstate co-authored papers		
No. of collaborating states		1
No. of Institutional Addresses		2

Publication in Major Disciplines:

Disciplines	1990	1994	Avg_IF '94	Nat Avg_IF '94
Mathematics				0.52
Physics				1.61
Chemistry				1.26
Earth & Space Sciences				0.81
Biology				1.43
Agriculture				0.68
Biomedical Research			0.52	1.58
Material Science				0.79
Engg & Technology				0.59
Computer & Comm Sci				0.80
Clinical Medicine				1.92
Multidisciplinary				0.81
			0.52	1.33

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity

High Visibility	Growing Visibility	Declining Visibility

state1

Publication Profile of Indian States

Tripura (Population : 2757205)

	1990	1994
No. of papers	4	8
National Rank	25	24
% of Total	0.04	0.07
Average Impact Factor	0.55	0.59
Internationally co-authored papers	1 (25.0%)	2 (25.0%)
Interstate co-authored papers	-	4 (50.0%)
No. of collaborating states		4
No. of Institutional Addresses		6

Publication in Major Disciplines:

Disciplines	90	94	Avg_IF '94	Nat Avg_IF '94
Mathematics	1	-	-	0.52
Physics	-	1	0.76	1.61
Chemistry	1	2	0.29	1.26
Earth & Space Sciences	-	1	1.23	0.81
Biology	2	2	0.89	1.43
Agriculture	-	1	0.09	0.68
Biomedical Research	-	-	-	1.58
Material Science	-	-	-	0.79
Engg & Technology	-	-	-	0.59
Computer & Comm Sci	-	-	-	0.80
Clinical Medicine	-	-	-	1.92
Multi-Disciplinary	-	1	0.27	0.81
Total	***4***	***8***	***0.59***	***1.33***

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity

High Visibility	Growing Visibility	Declining Visibility

state1

Publication Profile of Indian States

Tamil Nadu (Population : 55858946)

	1990	1994
No. of papers	841	1144
National Rank	7	6
% of Total	7.88	9.37
Average Impact Factor	1.22	1.15
Internationally co-authored papers	104 (12.4%)	118 (10.3%)
Interstate co-authored papers	79 (9.4%)	134 (11.7%)
No. of collaborating states	11	20
No. of Institutional Addresses		186

Publication in Major Disciplines:

Disciplines	1990	1994	Avg_IF '94	Nat Avg_IF '94
Mathematics	11	23	0.51	0.52
Physics	216	227	1.404	1.61
Chemistry	152	239	1.121	1.26
Earth & Space Sciences	10	22	0.601	0.81
Biology	37	55	0.998	1.43
Agriculture	21	14	0.356	0.68
Biomedical Research	54	94	1.236	1.58
Material Science	50	66	0.593	0.79
Engg & Technology	94	127	0.57	0.59
Computer & Comm Sci	9	13	0.891	0.80
Clinical Medicine	153	213	1.712	1.92
Multi-Disciplinary	34	51	0.717	0.81
Total	**841**	**1144**	**1.15**	**1.33**

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
Material Sciences	Maths	Comp & Comm Sci
Engg & Technology	Chemistry	Physics
Clinical Medicine	Biology	Agriculture
Maths		

High Visibility	Growing Visibility	Declining Visibility
Material Sciences	Maths	Comp & Comm Sci
Comp & Comm Sci	Multi-Disciplinary	
Engg & Technology		

state1

Publication Profile of Indian States

Uttar Pradesh (Population : 139112287)

	1990	1994
No. of papers	1541	1501
National Rank	2	2
% of Total	14.44	12.3
Average Impact Factor	1.02	1.18
Internationally co-authored papers	120 (7.8%)	199 (13.3%)
Interstate co-authored papers	139 (9.0%)	212 (14.1%)
No. of collaborating states	22	24
No. of Institutional Addresses		190

Publication in Major Disciplines:

Disciplines	1990	1994	Avg_IF '94	Nat Avg_IF '94
Mathematics	16	26	0.41	0.52
Physics	249	226	1.44	1.61
Chemistry	354	322	1.11	1.26
Earth & Space Sciences	95	88	0.67	0.81
Biology	128	107	1.76	1.43
Agriculture	65	33	0.63	0.68
Biomedical Research	131	148	1.09	1.58
Material Science	42	33	0.69	0.79
Engg & Technology	156	187	0.53	0.59
Computer & Comm Sci	0	11	0.53	0.80
Clinical Medicine	248	234	1.90	1.92
Multi-Disciplinary	57	86	0.83	0.81
Total	**3531**	**3495**	**1.18**	**1.33**

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
Biology	Comp & Comm Sci	Earth & Space Sciences
Engg & Technology	Maths	Agriculture
Earth & Space Sciences		
Multi-Disciplinary		

High Visibility	Growing Visibility	Declining Visibility
Biology	Comp & Comm Sci	Earth & Space Sciences
Engg & Technology	Biology	Agriculture
Multi-Disciplinary		

state1

Publication Profile of Indian States

West Bengal (Population : 67982732)

	1990	1994
No. of papers	1220	1373
National Rank	3	3
% of Total	11.44	11.25
Average Impact Factor	1.26	1.26
Internationally co-authored papers	107 (8.77%)	152 (11.1%)
Interstate co-authored papers	83 (6.8%)	129 9.4%)
No. of collaborating states	15	26
No. of Institutional Addresses		181

Publication in Major Disciplines:

Disciplines	1990	1994	Avg_IF '94	Nat Avg_IF '94
Mathematics	25	23	0.70	0.52
Physics	385	455	1.57	1.61
Chemistry	283	306	1.18	1.26
Earth & Space Sciences	44	47	0.82	0.81
Biology	63	41	0.93	1.43
Agriculture	18	22	0.72	0.68
Biomedical Research	134	145	1.61	1.58
Material Science	62	61	0.81	0.79
Engg & Technology	77	104	0.62	0.59
Computer & Comm Sci	16	34	0.80	0.80
Clinical Medicine	91	114	1.40	1.92
Multi-Disciplinary	22	21	0.27	0.81
Total	***1220***	***1373***	***1.26***	***1.33***

Comparison with National Averages (Activity, Visibility)

Areas of High Activity	Growing Activity	Declining Activity
Comp & Comm Sci	Agriculture	Biology
Physics		Biomedical Research
Material Sciences		Maths

High Visibility	Growing Visibility	Declining Visibility
Comp & Comm Sci	Comp & Comm Sci	Multi-Disciplinary
Material Sciences	Agriculture	Biology
Physics		
Maths		

8 Scientific Output of Institutions

There were more than 17,000 addresses located in India in the SCI database for the years 1990 and 1994, of which 98.8 percent were institutional addresses and 0.2 percent were residential or private addresses. The institutional output was highly skewed, a few major institutions contributing a large percentage of the output. It may be said that the activities of these institutions constitute the core of Indian science.

As the unit of analysis gets smaller down to the institutional level, the question of data reliability and fluctuation, becomes more acute. The interpretation of institutional productivity therefore needs to made with greater care. In this study no attempt has been made to adjust for differences in size between institutions.

On the following pages we have shown the top 20 institutions in 1994, within in each of twelve disciplines within our data (Table 8.1a). It may be seen that this simple procedure picks out the top institutions that contribute not less than 1-2 percent of the literature in that discipline. This is fairly comprehensive and separates out the institutions with higher output from those with less output. In terms of actual output however, this procedure applies a cutoff at different levels of productivity in different areas, e.g., 40 papers in Physics and 3 papers in Mathematics.

The average impact factor of the papers contributed by a given institution in a given discipline are also shown in Table 8.1a. The top 10 institutions with the highest average impact factors in a given area are highlighted. Institutions which do not have sufficient output to be included in the top twenty within an area, but have high impact, fail to be identified.

Table 8.1a Number of Publications of Top 20 Indian Institutions in Different Disciplines(1994)

MATHEMATICS		MAX IF = 1.22			
S.No	INSTITUTE	CITY	NO.	Cumm %	AVG. IF
1	INDIAN STATISTICAL INSTITUTE	CALCUTTA	31	16.40%	0.65
2	TATA INSTITUTE OF FUNDAMENTAL RESEARCH	BOMBAY	27	14.29%	0.53
3	DELHI UNIVERSITY	NEW-DELHI	16	8.47%	0.47
4	INDIAN INSTITUTE OF SCIENCE	BANGALORE	12	6.35%	0.41
5	INDIAN INSTITUTE OF TECHNOLOGY (MADRAS)	MADRAS	9	4.76%	0.65
6	INDIAN INSTITUTE OF TECHNOLOGY (KANPUR)	KANPUR	8	4.23%	0.48
7	BANARAS HINDU UNIVERSITY	VARANASI	6	3.17%	0.43
8	INDIAN INSTITUTE OF TECHNOLOGY (DELHI)	NEW-DELHI	5	2.65%	0.43
9	INDIAN INSTITUTE OF TECHNOLOGY (KHARAGPUR)	KHARAGPUR	4	2.12%	0.67
10	INDIAN INSTITUTE OF TECHNOLOGY (BOMBAY)	BOMBAY	4	2.12%	0.46
11	VISVA BHARTI (SANTINIKETAN)	SANTINIKETAN	4	2.12%	0.61
12	POONA UNIVERSITY	POONA	4	2.12%	0.72
13	SPIC SCIENCE FOUNDATION	MADRAS	3	1.59%	0.36
14	INDIAN INSTITUTE OF MANAGEMENT CALCUTTA	CALCUTTA	3	1.59%	1.22
15	ST ALBERTS COLLEGE	COCHIN	3	1.59%	0.61
16	REGIONAL ENGINEERING COLLEGE	ROURKELA	3	1.59%	0.49
17	PANJAB UNIVERSITY	CHANDIGARH	3	1.59%	0.42
18	MADRAS UNIVERSITY	MADRAS	3	1.59%	0.52
19	JAMIA MILIA ISLAMIA	NEW-DELHI	3	1.59%	0.34
20	COCHIN UNIVERSITY OF SCIENCE & TECHNOLOGY	COCHIN	3	1.59%	0.61
	TOTAL		154	81.48%	

PHYSICS		MAX IF = 2.4			
S.No	INSTITUTE	CITY	NO.	Cumm %	AVG. IF
1	TATA INSTITUTE OF FUNDAMENTAL RESEARCH	BOMBAY	255	10.46%	2.19
2	INDIAN INSTITUTE OF SCIENCE	BANGALORE	204	8.37%	2.40
3	BHABHA ATOMIC RESEARCH CENTRE	BOMBAY	149	6.11%	1.76
4	JADAVPUR UNIVERSITY	CALCUTTA	95	3.90%	1.40
5	INDIAN ASSOC. FOR THE CULTIVATION OF SCI.	CALCUTTA	87	3.57%	1.54
6	NATIONAL PHYSICAL LABORATORY	NEW-DELHI	79	3.24%	1.60
7	INDIAN INSTITUTE OF TECHNOLOGY (BOMBAY)	BOMBAY	76	3.12%	2.16
8	INDIAN INSTITUTE OF TECHNOLOGY (MADRAS)	MADRAS	73	2.99%	1.19
9	HYDERABAD UNIVERSITY	HYDERABAD	72	2.95%	2.00
10	INDIAN INSTITUTE OF TECHNOLOGY (DELHI)	NEW-DELHI	71	2.91%	1.24
11	SAHA INSTITUTE OF NUCLEAR PHYSICS	CALCUTTA	71	2.91%	2.06
12	DELHI UNIVERSITY	NEW-DELHI	69	2.83%	1.67
13	INSTITUTE OF PHYSICS	BHUBANESWAR	69	2.83%	1.93
14	INDIAN INSTITUTE OF TECHNOLOGY (KANPUR)	KANPUR	63	2.58%	1.82
15	BANARAS HINDU UNIVERSITY	VARANASI	60	2.46%	1.30
16	CALCUTTA UNIVERSITY	CALCUTTA	58	2.38%	1.44
17	PHYSICAL RESEARCH LABORATORY	AHMEDABAD	44	1.80%	2.07
18	CENTRE FOR ADVANCED TECHNOLOGY	INDORE	43	1.76%	1.64
19	INDIAN INSTITUTE OF TECHNOLOGY (KHARAGPUR)	KHARAGPUR	42	1.72%	1.43
20	INDIAN INSTITUTE OF ASTROPHYSICS	BANGALORE	40	1.64%	1.93
	TOTAL		1720	70.55%	

Table 8.1a Number of Publications of Top 20 Indian Institutions in Different Disciplines(1994)

CHEMISTRY		MAX IF = 2.18			
S.No	INSTITUTE	CITY	NO.	Cumm %	AVG. IF
1	INDIAN INSTITUTE OF SCIENCE	BANGALORE	179	7.22%	1.80
2	BHABHA ATOMIC RESEARCH CENTRE	BOMBAY	162	6.53%	1.17
3	NATIONAL CHEMICAL LABORATORY	POONA	150	6.05%	2.06
4	INDIAN INSTITUTE OF CHEMICAL TECHNOLOGY	HYDERABAD	96	3.87%	1.58
5	INDIAN ASSOC. FOR THE CULTIVATION OF SCI.	CALCUTTA	90	3.63%	1.61
6	INDIAN INSTITUTE OF TECHNOLOGY (KHARAGPUR)	KHARAGPUR	80	3.23%	1.13
7	INDIAN INSTITUTE OF TECHNOLOGY (BOMBAY)	BOMBAY	74	2.98%	2.02
8	INDIAN INSTITUTE OF TECHNOLOGY (DELHI)	NEW-DELHI	72	2.90%	1.36
9	INDIAN INSTITUTE OF TECHNOLOGY (MADRAS)	MADRAS	66	2.66%	1.46
10	HYDERABAD UNIVERSITY	HYDERABAD	64	2.58%	1.90
11	BANARAS HINDU UNIVERSITY	VARANASI	62	2.50%	0.96
12	INDIAN INSTITUTE OF TECHNOLOGY (KANPUR)	KANPUR	60	2.42%	2.13
13	DELHI UNIVERSITY	NEW-DELHI	45	1.81%	1.04
14	CENTRAL DRUGS RESEARCH INSTITUTE	LUCKNOW	45	1.81%	0.57
15	JADAVPUR UNIVERSITY	CALCUTTA	43	1.73%	1.22
16	KURUKSHETRA UNIVERSITY	KURUKSHETRA	42	1.69%	0.62
17	RAJASTHAN UNIVERSITY	JAIPUR	39	1.57%	1.00
18	PANJAB UNIVERSITY	CHANDIGARH	38	1.53%	1.13
19	MADRAS UNIVERSITY	MADRAS	37	1.49%	1.06
20	OSMANIA UNIVERSITY	HYDERABAD	36	1.45%	2.18
	TOTAL		1480	59.68%	

BIOLOGY		MAX IF = 3.45			
S.No	INSTITUTE	CITY	NO.	Cumm %	AVG. IF
1	ALIGARH MUSLIM UNIVERSITY	ALIGARH	39	7.01%	3.57
2	INTER. CROPS RES. INST. OF SEMI ARID TROP. CTR	PATANCHERU	29	5.22%	0.61
3	DELHI UNIVERSITY	NEW-DELHI	25	4.50%	1.50
4	CH. CHARAN SINGH HARYANA AGR. UNIVERSITY	HISAR	17	3.06%	0.62
5	INDIAN AGRICULTRAL RESEARCH INSTITUTE	NEW-DELHI	16	2.88%	0.75
6	CENTRAL INST. OF MED. & AROMATIC PLANTS	LUCKNOW	16	2.88%	1.04
7	BHABHA ATOMIC RESEARCH CENTRE	BOMBAY	16	2.88%	1.04
8	PUNJAB AGRICULTURAL UNIVERSITY	LUDHIANA	14	2.52%	1.77
9	BANARAS HINDU UNIVERSITY	VARANASI	14	2.52%	1.03
10	INDIAN INSTITUTE OF SCIENCE	BANGALORE	13	2.34%	2.04
11	MADURAI KAMARAJ UNIVERSITY	MADURAI	12	2.16%	0.71
12	NATIONAL INSTITUTE OF OCEANOGRAPHY	PANAJI	12	2.16%	0.65
13	MADRAS UNIVERSITY	MADRAS	11	1.98%	0.95
14	CALCUTTA UNIVERSITY	CALCUTTA	10	1.80%	1.11
15	MAHARSHI DAYANAND UNIVERSITY	ROHTAK	9	1.62%	0.64
16	HYDERABAD UNIVERSITY	HYDERABAD	9	1.62%	2.46
17	BOSE INSTITUTE	CALCUTTA	9	1.62%	1.24
18	NATIONAL CHEMICAL LABORATORY	POONA	9	1.62%	1.41
19	INDIAN INSTITUTE OF CHEMICAL TECHNOLOGY	HYDERABAD	9	1.62%	1.43
20	TAMIL NADU AGRICULTURAL UNIVERSITY	COIMBATORE	8	1.44%	0.70
	TOTAL		297	53.42%	

Table 8.1a Number of Publications of Top 20 Indian Institutions in Different Disciplines(1994)

EARTH & SPACE SCIENCES		MAX IF = 1.4			
S.No	INSTITUTE	CITY	NO.	Cumm %	AVG. IF
1	NATIONAL INSTITUTE OF OCEANOGRAPHY	PANAJI	36	7.14%	1.18
2	PHYSICAL RESEARCH LABORATORY	AHMEDABAD	35	6.94%	1.40
3	NATIONAL GEOPHYSICAL RESEARCH INSTITUTE	HYDERABAD	25	4.96%	1.12
4	SPACE APPLICATION CENTRE	AHMEDABAD	17	3.37%	0.77
5	INDIAN INSTITUTE OF TECHNOLOGY (DELHI)	NEW-DELHI	16	3.17%	0.54
6	BANARAS HINDU UNIVERSITY	VARANASI	15	2.98%	0.47
7	INDIAN INSTITUTE OF TROPICAL METEOROLOGY	POONA	15	2.98%	0.54
8	JADAVPUR UNIVERSITY	CALCUTTA	14	2.78%	0.85
9	VIKRAM SARABHAI SPACE CENTRE	TRIVANDRUM	12	2.38%	1.05
10	INDIAN INSTITUTE OF GEOMAGNATISM	BOMBAY	12	2.38%	0.66
11	INDIAN INSTITUTE OF TECHNOLOGY (MADRAS)	MADRAS	11	2.18%	0.29
12	INDIAN INSTITUTE OF TECHNOLOGY (BOMBAY)	BOMBAY	11	2.18%	0.68
13	DELHI UNIVERSITY	NEW-DELHI	11	2.18%	0.78
14	NATIONAL PHYSICAL LABORATORY	NEW-DELHI	11	2.18%	1.09
15	INDUSTRIAL TOXICOLOGY RESEARCH CENTRE	LUCKNOW	11	2.18%	0.30
16	BHABHA ATOMIC RESEARCH CENTRE	BOMBAY	11	2.18%	0.99
17	INDIAN INSTITUTE OF SCIENCE	BANGALORE	10	1.98%	0.77
18	ROORKEE UNIVERSITY	ROORKEE	10	1.98%	1.00
19	GEOLOGICAL SURVEY OF INDIA	NAGPUR	10	1.98%	0.79
20	INDIAN INSTITUTE OF TECHNOLOGY (KANPUR)	KANPUR	9	1.79%	0.82
	TOTAL		302	59.92%	

AGRICULTURE		MAX IF = 1.47			
S.No	INSTITUTE	CITY	NO.	Cumm %	AVG. IF
1	INTER. CROPS RES. INST. OF SEMI ARID TROP. CTR	PATANCHERU	37	13.03%	0.69
2	CENTRAL FOOD TECHNOL. RES. INSTITUTE	MYSORE	30	10.56%	0.87
3	PUNJAB AGRICULTURAL UNIVERSITY	LUDHIANA	23	8.10%	0.53
4	CH. CHARAN SINGH HARYANA AGR. UNIVERSITY	HISAR	18	6.34%	0.63
5	GB PANT UNIVERSITY OF AGR. & TECH.	PANTNAGAR	17	5.99%	0.47
6	INDIAN AGRICULTRAL RESEARCH INSTITUTE	NEW-DELHI	14	4.93%	0.62
7	INDIAN INSTITUTE OF TECHNOLOGY (KHARAGPUR)	KHARAGPUR	9	3.17%	0.58
8	BANARAS HINDU UNIVERSITY	VARANASI	7	2.46%	0.69
9	BHABHA ATOMIC RESEARCH CENTRE	BOMBAY	7	2.46%	0.83
10	MYSORE UNIVERSITY	MYSORE	6	2.11%	0.33
11	CENTRAL SOIL SALINITY RESEARCH INSTITUTE	KARNAL	6	2.11%	0.45
12	CENTRAL RICE RESEARCH INSTITUTE	CUTTACK	6	2.11%	0.65
13	UNIVERSITY OF AGRICULTURAL SCIENCES	BANGALORE	5	1.76%	0.52
14	HIMACHAL PRADESH KRISHI VISHWAVIDYALAYA	PALAMPUR	5	1.76%	0.74
15	CALCUTTA UNIVERSITY	CALCUTTA	5	1.76%	0.68
16	NATIONAL DAIRY RESEARCH INSTITUTE	KARNAL	5	1.76%	1.47
17	KUMAUN UNIVERSITY	NAINI-TAL	4	1.41%	0.85
18	KERALA AGRICULTURAL UNIVERSITY	TRISSUR	4	1.41%	0.34
19	GUJARAT AGRICULTURAL UNIVERSITY	NAVSARI	4	1.41%	0.48
20	NATIONAL DAIRY RESEARCH INSTITUTE	BANGALORE	4	1.41%	1.04
	TOTAL		216	76.06%	

Table 8.1a Number of Publications of Top 20 Indian Institutions in Different Disciplines(1994)

CLINICAL MEDICINE		MAX IF = 2.88			
S.No	INSTITUTE	CITY	NO.	Cumm %	AVG. IF
1	ALL INDIA INSTITUTE OF MEDICAL SCIENCES	NEW-DELHI	249	14.19%	2.08
2	POST GRADUATE INST.OF MED. EDUCATION & RES.	CHANDIGARH	159	9.06%	1.98
3	CHRISTIAN MEDICAL COLLEGE VELLORE ASSOC.	VELLORE	139	7.92%	1.50
4	SANJAY GANDHI PG INST. OF MEDICAL SCIENCES	LUCKNOW	99	5.64%	2.04
5	TATA MEMORIAL CENTRE	BOMBAY	80	4.56%	1.84
6	NIMHANS	BANGALORE	63	3.59%	2.27
7	BANARAS HINDU UNIVERSITY	VARANASI	52	2.96%	2.88
8	KASTURBA GANDHI MED. COLLEGE & HOSPITAL	MANIPAL	44	2.51%	1.53
9	CENTRAL DRUGS RESEARCH INSTITUTE	LUCKNOW	44	2.51%	1.56
10	REGIONAL CANCER CENTRE	TRIVANDRUM	38	2.17%	1.55
11	JAWAHARLAL INST. OF PG MED. EDU. & RES.	PONDICHERRY	30	1.71%	1.52
12	NATIONAL INSTITUTE OF IMMUNOLOGY	NEW-DELHI	30	1.71%	2.45
13	NIZAM'S INSTITUTE OF MEDICAL SCIENCES	HYDERABAD	29	1.65%	2.83
14	INDUSTRIAL TOXICOLOGY RESEARCH CENTRE	LUCKNOW	26	1.48%	1.67
15	GUJARAT CANCER & RESEARCH INSTITUTE	AHMEDABAD	25	1.42%	1.02
16	BHABHA ATOMIC RESEARCH CENTRE	BOMBAY	25	1.42%	1.79
17	KEM HOSPITAL BOMBAY	BOMBAY	24	1.37%	2.55
18	CALCUTTA UNIVERSITY	CALCUTTA	23	1.31%	1.44
19	SETH GS MEDICAL COLLEGE	BOMBAY	21	1.20%	1.16
20	SREE CHITRA TIRUNAL INST. OF MED. SCI. & TECH.	TRIVANDRUM	21	1.20%	0.65
	TOTAL		1221	69.57%	

BIOMEDICAL RESEARCH		MAX IF = 4.42			
S.No	INSTITUTE	CITY	NO.	Cumm %	AVG. IF
1	INDIAN INSTITUTE OF SCIENCE	BANGALORE	92	7.99%	2.65
2	CENTRE FOR CELLULAR & MOLECULAR BIOLOGY	HYDERABAD	52	4.52%	2.44
3	BANARAS HINDU UNIVERSITY	VARANASI	45	3.91%	1.07
4	POST GRADUATE INST.OF MED. EDUCATION & RES.	CHANDIGARH	40	3.48%	0.96
5	INDIAN INSTITUTE OF CHEMICAL BIOLOGY	CALCUTTA	40	3.48%	1.89
6	JAWAHARLAL NEHRU UNIVERSITY	NEW-DELHI	33	2.87%	1.75
7	ALL INDIA INSTITUTE OF MEDICAL SCIENCES	NEW-DELHI	33	2.87%	1.65
8	BHABHA ATOMIC RESEARCH CENTRE	BOMBAY	33	2.87%	1.58
9	DELHI UNIVERSITY	NEW-DELHI	32	2.78%	1.70
10	CENTRAL FOOD TECHNOL. RES. INSTITUTE	MYSORE	31	2.69%	1.51
11	CENTRAL DRUGS RESEARCH INSTITUTE	LUCKNOW	30	2.61%	1.16
12	ALIGARH MUSLIM UNIVERSITY	ALIGARH	28	2.43%	0.63
13	INDIAN INSTITUTE OF TECHNOLOGY (DELHI)	NEW-DELHI	27	2.35%	1.10
14	MADRAS UNIVERSITY	MADRAS	27	2.35%	1.08
15	NATIONAL CHEMICAL LABORATORY	POONA	27	2.35%	1.95
16	BOSE INSTITUTE	CALCUTTA	26	2.26%	2.31
17	HYDERABAD UNIVERSITY	HYDERABAD	24	2.09%	1.35
18	TATA INSTITUTE OF FUNDAMENTAL RESEARCH	BOMBAY	22	1.91%	4.42
19	CALCUTTA UNIVERSITY	CALCUTTA	21	1.82%	2.38
20	NATIONAL INSTITUTE OF IMMUNOLOGY	NEW-DELHI	19	1.65%	3.13
	TOTAL		682	59.25%	

Table 8.1a Number of Publications of Top 20 Indian Institutions in Different Disciplines(1994)

ENGINEERING & TECHNOLOGY		MAX IF = 0.81			
S.No	INSTITUTE	CITY	NO.	Cumm %	AVG. IF
1	INDIAN INSTITUTE OF SCIENCE	BANGALORE	114	12.50%	0.67
2	INDIAN INSTITUTE OF TECHNOLOGY (DELHI)	NEW-DELHI	68	7.46%	0.50
3	INDIAN INSTITUTE OF TECHNOLOGY (MADRAS)	MADRAS	65	7.13%	0.55
4	INDIAN INSTITUTE OF TECHNOLOGY (KHARAGPUR)	KHARAGPUR	65	7.13%	0.67
5	INDIAN INSTITUTE OF TECHNOLOGY (KANPUR)	KANPUR	64	7.02%	0.62
6	BHABHA ATOMIC RESEARCH CENTRE	BOMBAY	52	5.70%	0.80
7	BANARAS HINDU UNIVERSITY	VARANASI	48	5.26%	0.61
8	ROORKEE UNIVERSITY	ROORKEE	34	3.73%	0.53
9	INDIAN INSTITUTE OF TECHNOLOGY (BOMBAY)	BOMBAY	25	2.74%	0.73
10	INDIRA GANDHI CENTRE FOR ATOMIC RESEARCH	KALPAKKAM	24	2.63%	0.70
11	BOMBAY UNIVERSITY	BOMBAY	20	2.19%	0.79
12	NATIONAL CHEMICAL LABORATORY	POONA	20	2.19%	0.81
13	DEFENCE METALLURGICAL RES. LABORATORY	HYDERABAD	19	2.08%	0.70
14	MEERUT UNIVERSITY	MEERUT	16	1.75%	0.17
15	SRI VENKATESWARA UNIVERSITY	KURNOOL	13	1.43%	0.77
16	VIKRAM SARABHAI SPACE CENTRE	TRIVANDRUM	13	1.43%	0.48
17	TATA INSTITUTE OF FUNDAMENTAL RESEARCH	BOMBAY	13	1.43%	0.22
18	REGIONAL ENGINEERING COLLEGE	TIRUCHCHIRAPPALLI	12	1.32%	0.39
19	CALCUTTA UNIVERSITY	CALCUTTA	11	1.21%	0.62
20	ANNA UNIVERSITY	MADRAS	11	1.21%	0.44
	TOTAL		707	77.52%	

COMPUTER & COMMUNICATION SCIENCES		MAX IF = 1.38			
S.No	INSTITUTE	CITY	NO.	Cumm %	AVG. IF
1	INDIAN INSTITUTE OF SCIENCE	BANGALORE	23	17.56%	0.86
2	INDIAN STATISTICAL INSTITUTE	CALCUTTA	21	16.03%	0.74
3	INDIAN INSTITUTE OF TECHNOLOGY (KHARAGPUR)	KHARAGPUR	13	9.92%	0.87
4	INDIAN INSTITUTE OF TECHNOLOGY (MADRAS)	MADRAS	10	7.63%	0.80
5	DELHI UNIVERSITY	NEW-DELHI	10	7.63%	0.57
6	INDIAN INSTITUTE OF TECHNOLOGY (DELHI)	NEW-DELHI	8	6.11%	0.60
7	INDIAN INSTITUTE OF TECHNOLOGY (BOMBAY)	BOMBAY	7	5.34%	0.85
8	HARCOURT BUTLER TECHNOLOGY INSTITUTE	KANPUR	3	2.29%	0.58
9	INDIAN INSTITUTE OF TECHNOLOGY (KANPUR)	KANPUR	3	2.29%	0.75
10	BHARATHIDASAN UNIVERSITY	TIRUCHCHIRAPPALLI	3	2.29%	1.30
11	NATIONAL METALLURGICAL LABORATORY	JAMSHEDPUR	3	2.29%	1.38
12	TATA INSTITUTE OF FUNDAMENTAL RESEARCH	BOMBAY	3	2.29%	0.90
13	MAHARSHI DAYANAND UNIVERSITY	ROHTAK	2	1.53%	0.27
14	JADAVPUR UNIVERSITY	CALCUTTA	2	1.53%	0.83
15	CALCUTTA UNIVERSITY	CALCUTTA	2	1.53%	0.83
16	NIMHANS	BANGALORE	2	1.53%	0.64
17	RESEARCH & DEVELOPMENT DIVISION	HYDERABAD	1	0.76%	0.63
18	PRECIS AUTOMATIC & ROBOTIC INDIA	POONA	1	0.76%	0.87
19	MOTOROLA INDIA ELECTRONICS LTD	BANGALORE	1	0.76%	0.56
20	TILAK DHARI POST GRADUATE COLLEGE	JAUNPUR	1	0.76%	0.30
	TOTAL		119	90.84%	

Table 8.1a Number of Publications of Top 20 Indian Institutions in Different Disciplines(1994)

MATERIAL SCIENCES		MAX IF = 1.09			
S.No	INSTITUTE	CITY	NO.	Cumm %	AVG. IF
1	INDIAN INSTITUTE OF SCIENCE	BANGALORE	56	14.89%	1.09
2	INDIAN INSTITUTE OF TECHNOLOGY (KHARAGPUR)	KHARAGPUR	24	6.38%	0.65
3	INDIAN INSTITUTE OF TECHNOLOGY (MADRAS)	MADRAS	20	5.32%	0.56
4	INDIAN ASSOC. FOR THE CULTIVATION OF SCI.	CALCUTTA	18	4.79%	1.09
5	CENTRAL GLASS & CERAMIC RES. INST.	CALCUTTA	18	4.79%	0.71
6	INDIRA GANDHI CENTRE FOR ATOMIC RESEARCH	KALPAKKAM	18	4.79%	0.56
7	REGIONAL RESEARCH LABORATORY	TRIVANDRUM	16	4.26%	0.69
8	INDIAN INSTITUTE OF TECHNOLOGY (DELHI)	NEW-DELHI	14	3.72%	0.90
9	INDIAN INSTITUTE OF TECHNOLOGY (BOMBAY)	BOMBAY	13	3.46%	0.74
10	BANARAS HINDU UNIVERSITY	VARANASI	13	3.46%	0.77
11	ANNA UNIVERSITY	MADRAS	13	3.46%	0.59
12	NATIONAL PHYSICAL LABORATORY	NEW-DELHI	13	3.46%	0.81
13	BHABHA ATOMIC RESEARCH CENTRE	BOMBAY	12	3.19%	0.61
14	OSMANIA UNIVERSITY	HYDERABAD	10	2.66%	0.78
15	DEFENCE METALLURGICAL RES. LABORATORY	HYDERABAD	10	2.66%	0.92
16	INDIAN INSTITUTE OF TECHNOLOGY (KANPUR)	KANPUR	9	2.39%	0.50
17	MADRAS UNIVERSITY	MADRAS	9	2.39%	0.55
18	SHIVAJI UNIVERSITY	KOLHAPUR	7	1.86%	0.60
19	NATIONAL METALLURGICAL LABORATORY	JAMSHEDPUR	7	1.86%	0.75
20	SRI VENKATESWARA UNIVERSITY	TIRUPATI	6	1.60%	0.78
	TOTAL		306	81.38%	

MULTIDISCIPLINARY		MAX IF = 1.05			
S.No	INSTITUTE	CITY	NO.	Cumm %	AVG. IF
1	INDIAN INSTITUTE OF SCIENCE	BANGALORE	61	11.07%	1.05
2	BANARAS HINDU UNIVERSITY	VARANASI	27	4.90%	0.29
3	BHABHA ATOMIC RESEARCH CENTRE	SHASTRI-NAGAR	18	3.27%	0.28
4	RAMAN RESEARCH INSTITUTE	BANGALORE	15	2.72%	0.27
5	NATIONAL AERONAUTICAL LABORATORY	BANGALORE	14	2.54%	0.27
6	NISTADS	NEW-DELHI	12	2.18%	0.24
7	CENTRE FOR CELLULAR & MOLECULAR BIOLOGY	HYDERABAD	12	2.18%	0.25
8	UNIVERSITY OF AGRICULTURAL SCIENCES	BANGALORE	11	2.00%	0.27
9	NATIONAL INSTITUTE OF OCEANOGRAPHY	PANAJI	11	2.00%	0.27
10	MADURAI KAMARAJ UNIVERSITY	MADURAI	10	1.81%	0.27
11	TATA INSTITUTE OF FUNDAMENTAL RESEARCH	BOMBAY	10	1.81%	2.79
12	INDIAN INSTITUTE OF TECHNOLOGY (BOMBAY)	BOMBAY	9	1.63%	0.26
13	DEPARTMENT OF SCIENCE & TECHNOLOGY	NEW-DELHI	9	1.63%	0.26
14	NATIONAL GEOPHYSICAL RESEARCH INSTITUTE	HYDERABAD	9	1.63%	0.27
15	NATIONAL CHEMICAL LABORATORY	POONA	9	1.63%	0.27
16	PANJAB UNIVERSITY	CHANDIGARH	8	1.45%	0.27
17	JAWAHARLAL NEHRU UNIVERSITY	NEW-DELHI	8	1.45%	0.27
18	DELHI UNIVERSITY	NEW-DELHI	8	1.45%	0.26
19	SREE CHITRA TIRUNAL INST. OF MED. SCI. & TECH.	TRIVANDRUM	8	1.45%	0.27
20	BOSE INSTITUTE	CALCUTTA	8	1.45%	0.28
	TOTAL		277	50.27%	

8.1 Inter institutional Comparison

A comparison of institutions in terms of their output of papers and impact appears possible in principle. However, in practice it presents several difficulties. The average output and average impact factor of the disciplines varies considerably at the national level. Again, the proportion of papers in different disciplines varies sharply between institutions. This is to be expected as institutions often specialize in a few or even in a single discipline. Thus comparisons may be made on the basis of the IF of papers contributed by the institutions within a single discipline, as has been done in Table 8.1a. We may be able to say for example that Institution X is 'better' than Institution Y in Physics. It is not entirely meaningful to make a direct comparison of institutions using their average IF's irrespective of discipline.

In spite of the limitations noted above, we have attempted to group the institutions into the following categories

more productive and effective	(higher output, higher IF)
more productive but less effective	(higher output, lower IF)
less productive but effective	(lower output, higher IF).
less productive, less effective	(lower output, lower IF)

The divisions between categories are effected by taking the top 50 institutions in terms of output, and splitting them with respect to the mean value of output and Impact Factor , to lie either above or below the mean in each case.

8.2 Top Institutions

In order to assess and compare the contribution of the top institutions, the institution names had to be standardized, as they appeared under several forms. The institutional output for the top 50 institutions in the years 1994 and 1990, in terms of total papers in each discipline, was ascertained (Tables 8.1b and 8.1c). We then selected the top 50 institutions in terms of output from the 1994 data, based on the additional condition that they should also have been among the top forty institutions of 1990. These 'elite' institutions which accounted for 7395 papers in 1994, or about 65.4 percent of the literature from India as reflected in the *SCI*, have been compared in terms of output and impact in Section 8.3

Table 8.1b SCIENTIFIC OUTPUT AND AVERAGE IMPACT OF INDIAN INSTITUTIONS IN DIFFERENT DISCIPLINES : SCI DATA 1994

RANK	INSTITUTE	MAT	PHY	CHE	BIO	GEO	AGRI	MED	BMD	ENGG	MTL	MUL	COMP	TOTAL	AVG_IF
1	INDIAN INSTITUTE OF SCIENCE	9	164	151	10	10	2	12	79	97	49	53	21	657	1 682
2	BHABHA ATOMIC RESEARCH CENTRE		135	137	15	11	7	23	30	45	10	16		429	1 355
3	TATA INSTITUTE OF FUNDAMENTAL RESEARCH	27	253	15	1	1		6	21	13	1	9	1	348	2 168
4	BANARAS HINDU UNIVERSITY	6	54	62	14	14	7	41	41	43	11	25		318	1 171
5	INDIAN INSTITUTE OF TECHNOLOGY (DELHI)	5	69	67	1	12	1	2	26	64	13	7	8	275	0 967
6	INDIAN INSTITUTE OF TECHNOLOGY (MADRAS)	9	68	65	3	8	2	1	9	62	18	6	9	260	0 966
7	INDIAN INSTITUTE OF TECHNOLOGY (KHARAGPUR)	4	38	72	2	8	8		2	60	23	1	12	230	0 969
8	NATIONAL CHEMICAL LABORATORY		14	142	9			1	26	20	5	9		226	1 821
9	DELHI UNIVERSITY	11	62	43	25	11	1	12	29	8	2	8	7	219	1 310
10	ALL INDIA INSTITUTE OF MEDICAL SCIENCES		2	3	1	1		180	28			3	1	219	2 340
11	INDIAN INSTITUTE OF TECHNOLOGY (BOMBAY)	4	70	64	4	10		3	10	25	11	9	7	217	1 602
12	INDIAN INSTITUTE OF TECHNOLOGY (KANPUR)	8	57	59		9		1	6	58	9	5	3	215	1 582
13	INDIAN ASSOCIATION FOR THE CULTIVATION OF SCIENCE		81	81				2	11	3	18	2		198	1 497
14	HYDERABAD UNIVERSITY	1	71	63	9	1		13	24		5	2	1	190	1 939
15	JADAVPUR UNIVERSITY	2	89	42	2	13		14	11	10	2	2	2	189	1 182
16	CALCUTTA UNIVERSITY	2	55	30	10	9	5	22	20	11	1	5	2	172	1 292
17	MADRAS UNIVERSITY	3	26	36	11	3	2	18	26	2	8	7	1	143	0 942
18	ALIGARH MUSLIM UNIVERSITY	2	23	34	34	1		8	27	2		4		135	1 442
19	POST GRADUATE INSTITUTE OF MEDICAL EDUCATION AND RESEARCH				1			101	30			2		134	1 654
20	INDIAN INSTITUTE OF CHEMICAL TECHNOLOGY		15	95	7	1	2	3	3	2	4	1	1	134	1 434
21	NATIONAL PHYSICAL LABORATORY	1	79	10		11	1			9	13	1		125	1 331
22	OSMANIA UNIVERSITY		30	36	7	4	1	7	17	7	9	4		122	1 620
23	JAWAHARLAL NEHRU UNIVERSITY	1	29	6	7	8	2	14	27		4	8	1	107	1 572
24	ROORKEE UNIVERSITY	2	25	21	1	9	1		5	33	4	5		106	1 011
25	CENTRAL DRUGS RESEARCH INSTITUTE		2	41	4			31	24			3		105	1 097
26	CHRISTIAN MEDICAL COLLEGE VELLORE ASSOCIATION				1			91	6			2		100	1 899
27	POONA UNIVERSITY	4	26	30	2	3		3	13	3	6	5	1	96	1 449
28	PANJAB UNIVERSITY	2	29	37		4	1	4	8			8		93	1 447
29	BOMBAY UNIVERSITY	2	15	33		1	1	11	1	20	3	2		89	0 933
30	SAHA INSTITUTE OF NUCLEAR PHYSICS		70	9				2	5		1		1	88	1 944
31	PHYSICAL RESEARCH LABORATORY		43			35				3		6		87	1 621
32	SANJAY GANDHI POST GRADUATE INSTITUTE OF MEDICAL SCIENCES							76	7			1		84	1 967
33	RAJASTHAN UNIVERSITY		25	38	1			8	2	2	4	3		83	0 969
34	INDIAN STATISTICAL INSTITUTE	30	15		1	5	1	1	5	1		1	18	78	0 808
35	CENTRAL FOOD TECHNOLOGICAL RESEARCH INSTITUTE			13	2		28	4	29			1		77	1 183
36	INDIRA GANDHI CENTRE FOR ATOMIC RESEARCH		20	12	1	1		1		22	18	1		76	1 071
37	INTER. CROPS RESEARCH INST. OF SEMI ARID TROPICAL CENTRE				29	1	36		7			2		75	0 725
38	REGIONAL RESEARCH LABORATORY		11	33	1		1		5	5	16	1		73	1 384
39	MADURAI KAMARAJ UNIVERSITY		13	19	12	1	1	5	10	1		10		72	1 002
40	CENTRE FOR CELLULAR & MOLECULAR BIOLOGY			3		1		4	52			12		72	2 120
41	ANNA UNIVERSITY		35	4		1		1	5	11	12	2		71	0 849
42	SRI VENKATESWARA UNIVERSITY		15	20	4	4		6	2	13	6			70	1 228
43	INSTITUTE OF PHYSICS		69	1										70	1 908
44	NORTH EASTERN HILL UNIVERSITY		25	23	6	1	2	1	9			2		69	0 998
45	MS UNIVERSITY OF BARODA	1	9	29	1	4	1	7	10	3	1	3		69	1 056
46	INDIAN INSTITUTE OF CHEMICAL BIOLOGY			11	5			15	36			2		69	2 050
47	PUNJAB AGRICULTURAL UNIVERSITY	2	5	4	14	2	22	3	11	3		1		67	1 072
48	KURUKSHETRA UNIVERSITY		8	42		2		7	2	1	2	3		67	1 025
49	BOSE INSTITUTE		15	7	9			5	23			6		65	1 448
50	MAHARSHI DAYANAND UNIVERSITY		13	24	9	2		1	3	6		2	2	62	0 630
	TOTAL	138	1972	1767	276	223	136	771	783	668	289	273	99	7395	1 436

Table 8.1c SCIENTIFIC OUTPUT OF INDIAN INSTITUTIONS IN DIFFERENT DISCIPLINES : SCI DATA 1990

INSTITUTE	MAT	PHY	CHE	BIO	GEO	AGRI	MED	BMD	ENGG	MTL	MUL	COMP	TOT	AVG_IF
INDIAN INSTITUTE OF SCIENCE	4	146	107	4	8	1	13	60	62	24	35	9	473	1 524
BHABHA ATOMIC RESEARCH CENTRE	1	148	130	14	4	11	19	30	27	6	11		401	1 369
TATA INSTITUTE OF FUNDAMENTAL RESEARCH	39	175	16		2		3	20	3	2	8	3	271	1 956
BANARAS HINDU UNIVERSITY	2	74	52	27	18	8	38	42	45	13	7		326	1 018
INDIAN INSTITUTE OF TECHNOLOGY (DELHI)	3	64	61		11	1	2	15	45	21	1	4	228	1 023
INDIAN INSTITUTE OF TECHNOLOGY (MADRAS)	2	80	52		1		1	5	48	17	2	2	210	0 919
INDIAN INSTITUTE OF TECHNOLOGY (KHARAGPUR)	2	44	48	7	11	8		1	33	35		7	196	1 001
NATIONAL CHEMICAL LABORATORY		19	84	3		1	1	21	14	8	3		154	1 649
DELHI UNIVERSITY	3	60	55	13	7	3	34	20	9	6	4		214	1 213
ALL INDIA INSTITUTE OF MEDICAL SCIENCES		3	1	1			171	14		1			191	2 046
INDIAN INSTITUTE OF TECHNOLOGY (BOMBAY)	7	36	63	3	4		7	6	32	4	1	5	168	1 462
INDIAN INSTITUTE OF TECHNOLOGY (KANPUR)	6	53	45		10			3	46	10	1		174	1 306
INDIAN ASSOCIATION FOR THE CULTIVATION OF SCIENCE		73	70		1		1	6	3	9			163	1 545
HYDERABAD UNIVERSITY	4	43	33	6	1	1	1	15	2	3	3		112	1 630
JADAVPUR UNIVERSITY	1	76	51		12		8	10	20	4			182	1 148
CALCUTTA UNIVERSITY	7	32	18	26	9	2	28	35	2	2	4	1	166	1 150
MADRAS UNIVERSITY	3	26	28	8	4	3	23	18		2	7		122	1 000
ALIGARH MUSLIM UNIVERSITY	2	16	58	10	3	2	18	13	4		6		132	0 697
POST GRADUATE INSTITUTE OF MEDICAL EDUCATION AND RESEARCH				2			144	21			1		168	1 402
INDIAN INSTITUTE OF CHEMICAL TECHNOLOGY		8	103	1	1	1	5	5	8	5	3		140	1 530
NATIONAL PHYSICAL LABORATORY		64	3		9			1	8	10	2		97	1 225
OSMANIA UNIVERSITY		26	62	1	5		7	7	7	10	10		135	1 109
JAWAHARLAL NEHRU UNIVERSITY		11	2	12	5	1	10	23	2		5	1	72	1 366
ROORKEE UNIVERSITY	2	14	31		12			5	27	5			96	1 044
CENTRAL DRUGS RESEARCH INSTITUTE		2	55	11	2		59	17			9		155	1 391
CHRISTIAN MEDICAL COLLEGE VELLORE ASSOCIATION							48	4					52	1 558
POONA UNIVERSITY		45	28	1			9	4	2	5	3		97	1 643
PANJAB UNIVERSITY	3	39	43	7	3	2	31	21	6	1	6		162	1 249
BOMBAY UNIVERSITY	2	11	25			2	1	1	24	1	1		68	0 818
SAHA INSTITUTE OF NUCLEAR PHYSICS		64	9				1	10			2		86	1 595
PHYSICAL RESEARCH LABORATORY		23		1	17			1			4		46	2 395
SANJAY GANDHI POST GRADUATE INSTITUTE OF MEDICAL SCIENCES							7				1		8	1 411
RAJASTHAN UNIVERSITY	3	39	54	4	3	1	10	2	4	2	5		127	0 849
INDIAN STATISTICAL INSTITUTE	26	16		3	4	1		4	2		1	4	61	1 223
CENTRAL FOOD TECHNOLOGICAL RESEARCH INSTITUTE		1	6	4	1	16		17			4		49	0 937
INDIRA GANDHI CENTRE FOR ATOMIC RESEARCH		24	5						22	6			57	1 039
INTERNATIONAL CROPS RESEARCH INSTITUTE OF SEMI ARID TROPICAL CENTRE				30	1	36	1	4	1		1		74	1 115
REGIONAL RESEARCH LABORATORY (KERALA)		4	15			3		3	4	11			40	0 966
MADURAI KAMARAJ UNIVERSITY		17	15	5		1	5	8			6		57	1 042
CENTRE FOR CELLULAR & MOLECULAR BIOLOGY		1	2		1		1	17			5		27	2 507
ANNA UNIVERSITY		25	7				2	1	5	11		1	52	1 998
SRI VENKATESWARA UNIVERSITY		17	36	4	7	2	2	23	2	12	5		110	0 863
INSTITUTE OF PHYSICS		25											25	2 196
NORTH EASTERN HILL UNIVERSITY	1	21	29	10	2		1	1	1		2		68	1 254
MS UNIVERSITY OF BARODA		3	20	5		1	5	11		1	4		50	0 991
INDIAN INSTITUTE OF CHEMICAL BIOLOGY			12	1			15	33	1		2	1	65	1 802
PUNJAB AGRICULTURAL UNIVERSITY	2	2	4	15		25	17	5	1		4		75	0 697
KURUKSHETRA UNIVERSITY	1	4	31	6	1		1	2	2		1		49	0 977
BOSE INSTITUTE		9	6	5			4	26			4		54	1 898
MAHARSHI DAYANAND UNIVERSITY		18	31	2	2					1	3		57	0 796
TOTAL	126	1701	1606	252	182	133	754	611	524	248	187	38	6362	1 314

8.3 Comparison between Elite institutions

Having initially selected top 50 institutions, it became possible to rate them among the elite collection with respect to the average for the group. This procedure separates out 4 categories within the institutional group, in terms of output and impact being above or below the group average. This implies a comparison between elite institutions and not in terms of national average. For example, the national average of the Impact Factor in all disciplines combined was 1.33 in 1994, as against the average of the 'elite' institutions which was 1.43.

It is possible to debate whether this is an appropriate method to classify institutions. However, our objective here is not to provide foolproof evidence of the membership of an institution within one or other category, but to demonstrate a methodology by which an inter-institutional comparison could be made. All calculations were based on the 1994 values of the Journal Impact Factor. Tables 8.2a and 8.2b show the list of elite institutions sub-divided into four categories , namely

Higher output, higher impact	Higher output, lower impact
Lower output, lower impact	Lower output and higher impact

Certain institutions that maintained their position in the *high-output-high impact* group in both years were *IISc, TIFR, NCL,IIT (Bombay), Indian Association for the Cultivation of Science.* others such as *Hyderabad University* moved up from lower than average output to the *high output-high impact* group, while *Panjab, Osmania* and *Aligarh Universities* moved from the *high output- low impact* group to the *low output-high impact* group, thus improving upon their Impact factor , even as their output fell between 1990 and 1994.

The ***Post Graduate Institute of Medical Research*** fell from the *high output-high impact* group to lower than average output, maintaining its impact above average.

IIT (Kanpur) and BARC moved from the *high output-high impact* group to the *high output-low impact* group, failing to maintain their higher than average impact.

IICT and *CDRI* fell from higher than average in both output and impact to lower than average on both counts.

Table 8.2a : Categories of Indian Institutions in terms of Output and Impact Factor 1994

INSTITUTE	DEVIATIONS FROM AVERAGE PAPERS	AVG_IF	O/P - IF	RANK ON TOTAL	
1 INDIAN INSTITUTE OF SCIENCE	509	0.246	++	1	Higher Output & Higher Impact
2 TATA INSTITUTE OF FUNDAMENTAL RESEARCH	200	0.732	++	3	
3 NATIONAL CHEMICAL LABORATORY	78	0.385	++	8	
4 ALL INDIA INSTITUTE OF MEDICAL SCIENCES	71	0.904	++	10	
5 INDIAN INSTITUTE OF TECHNOLOGY (BOMBAY)	69	0.166	++	11	
6 INDIAN INSTITUTE OF TECHNOLOGY (KANPUR)	67	0.146	++	12	
7 INDIAN ASSOCIATION FOR THE CULTIVATION OF SCIENCE	50	0.061	++	13	
8 HYDERABAD UNIVERSITY	42	0.503	++	14	
9 BHABHA ATOMIC RESEARCH CENTRE	281	-0.081	+-	2	Higher Output & Lower Impact
10 BANARAS HINDU UNIVERSITY	170	-0.265	+-	4	
11 INDIAN INSTITUTE OF TECHNOLOGY (DELHI)	127	-0.469	+-	5	
12 INDIAN INSTITUTE OF TECHNOLOGY (MADRAS)	112	-0.470	+-	6	
13 INDIAN INSTITUTE OF TECHNOLOGY (KHARAGPUR)	82	-0.467	+-	7	
14 DELHI UNIVERSITY	71	-0.126	+-	9	
15 JADAVPUR UNIVERSITY	41	-0.254	+-	15	
16 CALCUTTA UNIVERSITY	24	-0.144	+-	16	
17 ALIGARH MUSLIM UNIVERSITY	-13	0.006	-+	18	Lower Output & Higher Impact
18 POST GRADUATE INSTITUTE OF MEDICAL EDUCATION AND RESEARCH	-14	0.218	-+	19	
19 OSMANIA UNIVERSITY	-26	0.184	-+	22	
20 JAWAHARLAL NEHRU UNIVERSITY	-41	0.136	-+	23	
21 CHRISTIAN MEDICAL COLLEGE VELLORE ASSOCIATION	-48	0.463	-+	26	
22 POONA UNIVERSITY	-52	0.013	-+	27	
23 PANJAB UNIVERSITY	-55	0.011	-+	28	
24 SAHA INSTITUTE OF NUCLEAR PHYSICS	-60	0.508	-+	30	
25 PHYSICAL RESEARCH LABORATORY	-61	0.185	-+	31	
26 SANJAY GANDHI POST GRADUATE INSTITUTE OF MEDICAL SCIENCES	-64	0.531	-+	32	
27 CENTRE FOR CELLULAR & MOLECULAR BIOLOGY	-76	0.684	-+	40	
28 INSTITUTE OF PHYSICS	-78	0.472	-+	43	
29 INDIAN INSTITUTE OF CHEMICAL BIOLOGY	-79	0.614	-+	46	
30 BOSE INSTITUTE	-83	0.012	-+	49	
31 MADRAS UNIVERSITY	-5	-0.494	--	17	Lower Output & Lower Impact
32 INDIAN INSTITUTE OF CHEMICAL TECHNOLOGY	-14	-0.002	--	20	
33 NATIONAL PHYSICAL LABORATORY	-23	-0.105	--	21	
34 ROORKEE UNIVERSITY	-42	-0.425	--	24	
35 CENTRAL DRUGS RESEARCH INSTITUTE	-43	-0.339	--	25	
36 BOMBAY UNIVERSITY	-59	-0.503	--	29	
37 RAJASTHAN UNIVERSITY	-65	-0.467	--	33	
38 INDIAN STATISTICAL INSTITUTE	-70	-0.628	--	34	
39 CENTRAL FOOD TECHNOLOGICAL RESEARCH INSTITUTE	-71	-0.253	--	35	
40 INDIRA GANDHI CENTRE FOR ATOMIC RESEARCH	-72	-0.365	--	36	
41 INTER. CROPS RESEARCH INST. OF SEMI ARID TROPICAL CENTRE	-73	-0.711	--	37	
42 REGIONAL RESEARCH LABORATORY	-75	-0.052	--	38	
43 MADURAI KAMARAJ UNIVERSITY	-76	-0.434	--	39	
44 ANNA UNIVERSITY	-77	-0.587	--	41	
45 SRI VENKATESWARA UNIVERSITY	-78	-0.208	--	42	
46 MS UNIVERSITY OF BARODA	-79	-0.380	--	45	
47 NORTH EASTERN HILL UNIVERSITY	-79	-0.438	--	44	
48 PUNJAB AGRICULTURAL UNIVERSITY	-81	-0.364	--	47	
49 KURUKSHETRA UNIVERSITY	-81	-0.411	--	48	
50 MAHARSHI DAYANAND UNIVERSITY	-86	-0.806	--	50	
TOTAL	7395				

Table 8.2b : Categories of Indian Institutions in terms of Output and Impact Factor^ 1990

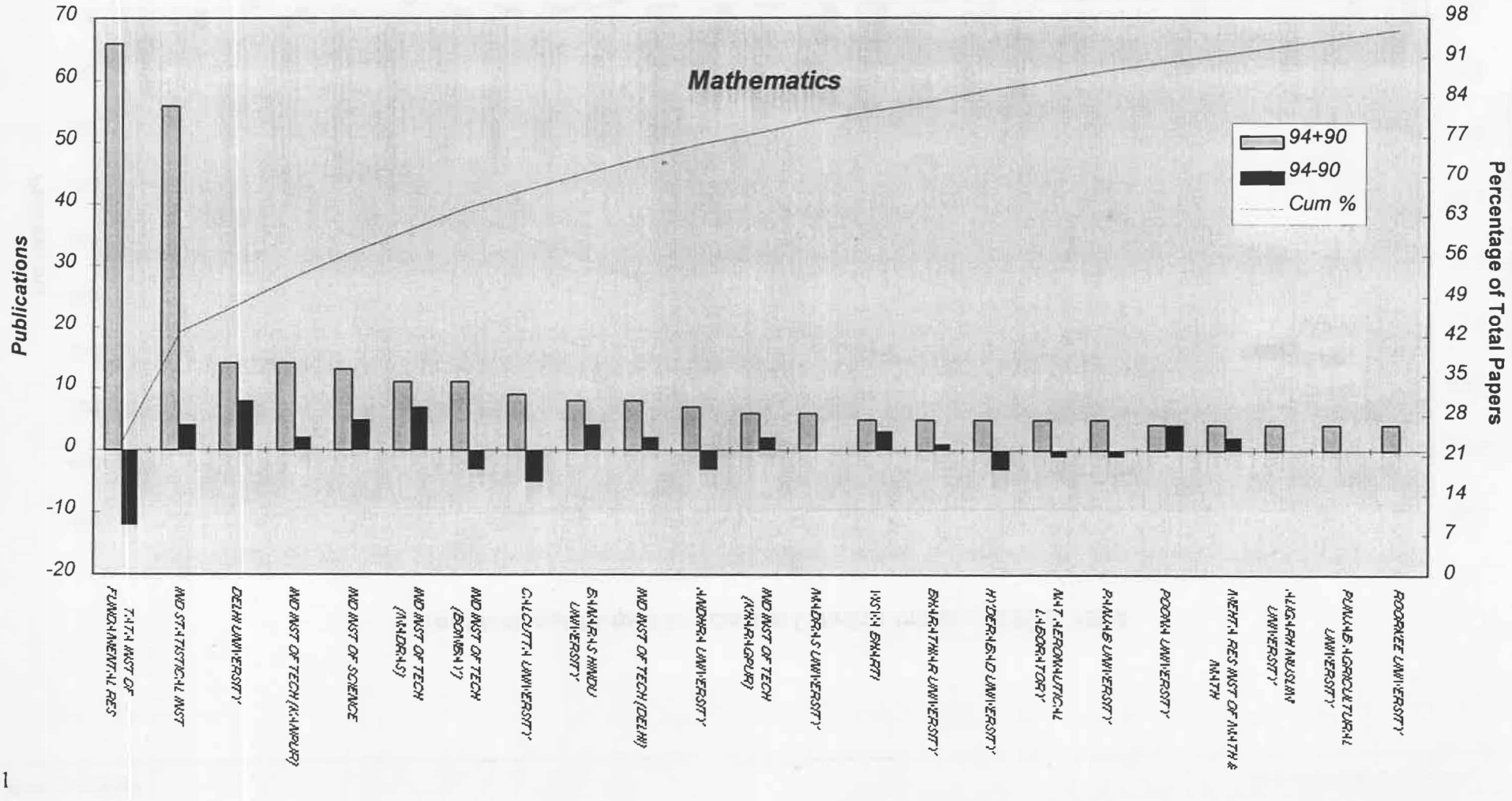
	INSTITUTE	DEVIATIONS FROM AVERAGE PAPERS	AVG_IF	O/P - IF	RANK ON TOTAL	
1	INDIAN INSTITUTE OF SCIENCE	346	0.210	++	1	Higher Output & Higher Impact
2	BHABHA ATOMIC RESEARCH CENTRE	274	0.055	++	2	
3	TATA INSTITUTE OF FUNDAMENTAL RESEARCH	144	0.642	++	4	
4	ALL INDIA INSTITUTE OF MEDICAL SCIENCES	64	0.732	++	9	
5	INDIAN INSTITUTE OF TECHNOLOGY (BOMBAY)	41	0.148	++	12	
6	PG INSTITUTE OF MEDICAL EDUCATION AND RESEARCH	41	0.088	++	13	
7	INDIAN ASSOCIATION FOR THE CULTIVATION OF SCIENCE	36	0.231	++	15	
8	CENTRAL DRUGS RESEARCH INSTITUTE	28	0.077	++	17	
9	NATIONAL CHEMICAL LABORATORY	27	0.335	++	18	
10	INDIAN INSTITUTE OF CHEMICAL TECHNOLOGY	13	0.216	++	19	
11	BANARAS HINDU UNIVERSITY	199	-0.296	+-	3	Higher Output & Lower Impact
12	INDIAN INSTITUTE OF TECHNOLOGY (DELHI)	101	-0.291	+-	5	
13	DELHI UNIVERSITY	87	-0.101	+-	6	
14	INDIAN INSTITUTE OF TECHNOLOGY (MADRAS)	83	-0.395	+-	7	
15	INDIAN INSTITUTE OF TECHNOLOGY (KHARAGPUR)	69	-0.313	+-	8	
16	JADAVPUR UNIVERSITY	55	-0.166	+-	10	
17	INDIAN INSTITUTE OF TECHNOLOGY (KANPUR)	47	-0.008	+-	11	
18	CALCUTTA UNIVERSITY	39	-0.164	+-	14	
19	PANJAB UNIVERSITY	35	-0.065	+-	16	
20	OSMANIA UNIVERSITY	8	-0.205	+-	20	
21	ALIGARH MUSLIM UNIVERSITY	5	-0.617	+-	21	
22	RAJASTHAN UNIVERSITY	0	-0.465	+-	22	
23	HYDERABAD UNIVERSITY	-15	0.316	-+	24	Lower Output & Higher Impact
24	POONA UNIVERSITY	-30	0.329	-+	26	
25	SAHA INSTITUTE OF NUCLEAR PHYSICS	-41	0.281	-+	29	
26	JAWAHARLAL NEHRU UNIVERSITY	-55	0.052	-+	32	
27	INDIAN INSTITUTE OF CHEMICAL BIOLOGY	-62	0.488	-+	35	
28	BOSE INSTITUTE	-73	0.584	-+	40	
29	ANNA UNIVERSITY	-75	0.684	-+	41	
30	CHRISTIAN MEDICAL COLLEGE VELLORE ASSOCIATION	-75	0.244	-+	42	
31	PHYSICAL RESEARCH LABORATORY	-81	1.081	-+	46	
32	CENTRE FOR CELLULAR & MOLECULAR BIOLOGY	-100	1.193	-+	48	
33	INSTITUTE OF PHYSICS	-102	0.882	-+	49	
34	SANJAY GANDHI PG INSTITUTE OF MEDICAL SCIENCES	-119	0.097	-+	50	
35	MADRAS UNIVERSITY	-5	-0.314	--	23	Lower Output & Lower Impact
36	SRI VENKATESWARA UNIVERSITY	-17	-0.451	--	25	
37	NATIONAL PHYSICAL LABORATORY	-30	-0.089	--	27	
38	ROORKEE UNIVERSITY	-31	-0.270	--	28	
39	PUNJAB AGRICULTURAL UNIVERSITY	-52	-0.617	--	30	
40	INTL CROPS RES INST OF SEMI ARID TROPICAL CENTRE	-53	-0.199	--	31	
41	NORTH EASTERN HILL UNIVERSITY	-59	-0.060	--	33	
42	BOMBAY UNIVERSITY	-59	-0.496	--	34	
43	INDIAN STATISTICAL INSTITUTE	-66	-0.091	--	36	
44	MADURAI KAMARAJ UNIVERSITY	-70	-0.272	--	37	
45	INDIRA GANDHI CENTRE FOR ATOMIC RESEARCH	-70	-0.275	--	38	
46	MAHARSHI DAYANAND UNIVERSITY	-70	-0.518	--	39	
47	MS UNIVERSITY OF BARODA	-77	-0.323	--	43	
48	KURUKSHETRA UNIVERSITY	-78	-0.337	--	44	
49	CENTRAL FOOD TECHNOLOGICAL RESEARCH INSTITUTE	-78	-0.377	--	45	
50	REGIONAL RESEARCH LABORATORY (KERALA)	-87	-0.348	--	47	
	TOTAL	6382				
	AVERAGE OUTPUT & IMPACT FACTOR	127.24	1.314			

8.4 Graphical Displays

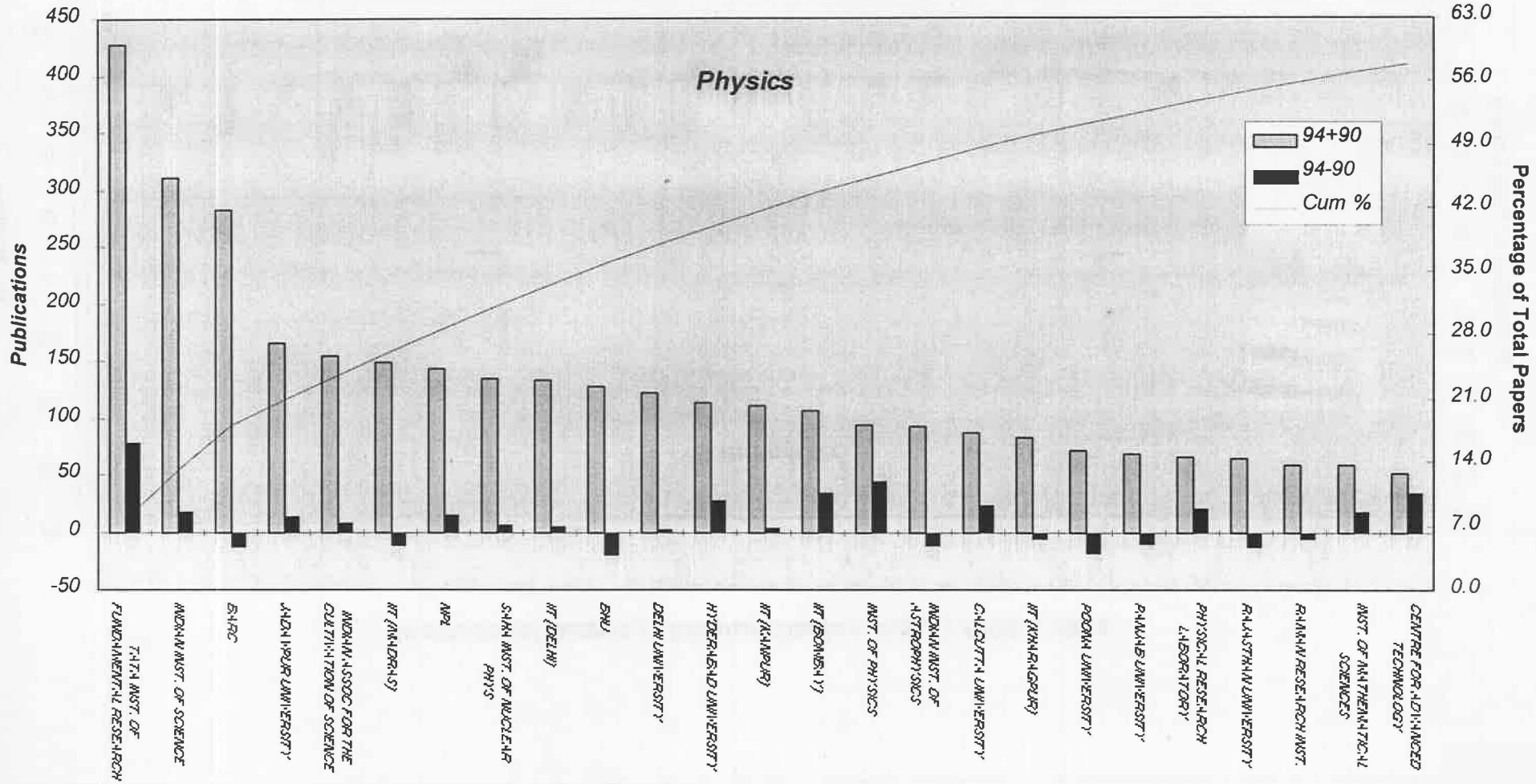
In this section, we have shown the institutions ordered by output in different disciplines, and their growth or decline (in terms of change in output in the 4 year interval .) In order to damp out the effect of year-to-year fluctuations, we have based our calculations on the aggregated data for the years 1990 and 1994. The difference between the output in the 2 years indicates change. Whether this is the effect of fluctuation or an actual trend due to specific causal factors can only be determined by analyzing several years of data. We have also indicated the cumulative percentage of output in any discipline accounted for by these institutions.

The set of 12 graphs (Fig.8.1a-l) rank the institutions in terms of their combined output in the years '90 and '94, and also show the change in their output in the interval of 4 years. Browsing through the displays generates a feeling for the actual output of any institution and its position within a discipline or field.

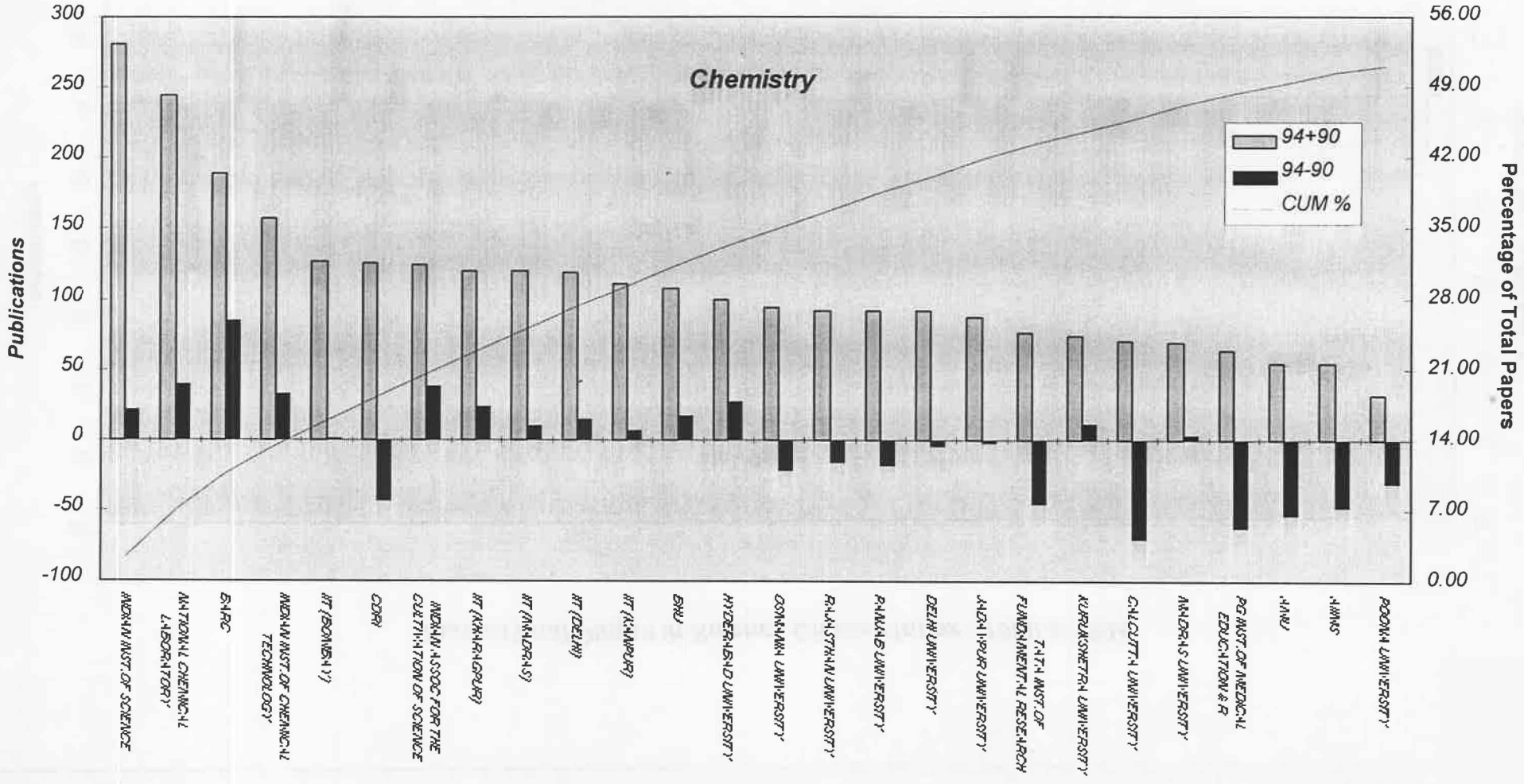
Institutional Output in Science Citation Index : 1990 & 1994



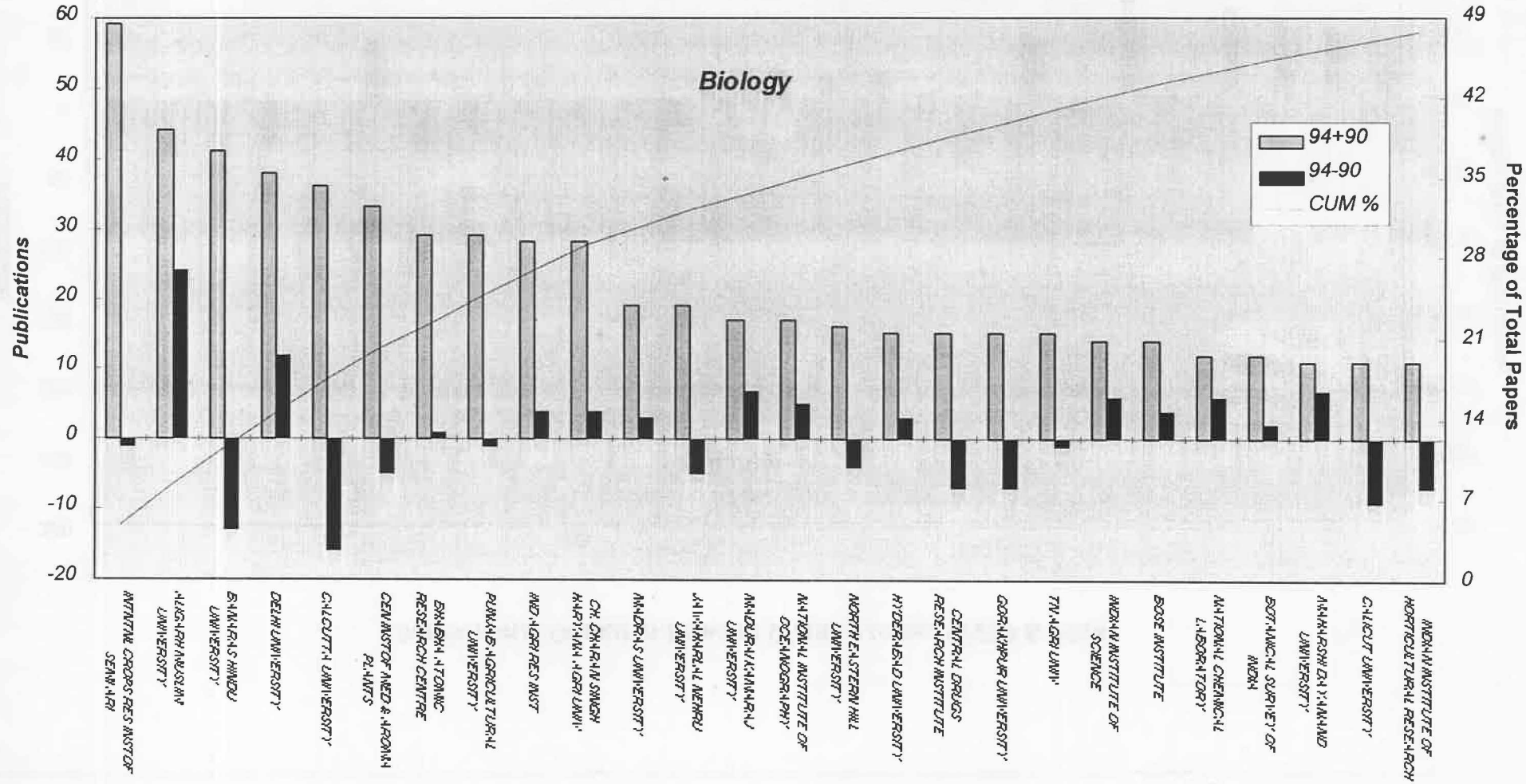
Institutional Output in Science Citation Index : 1990 & 1994



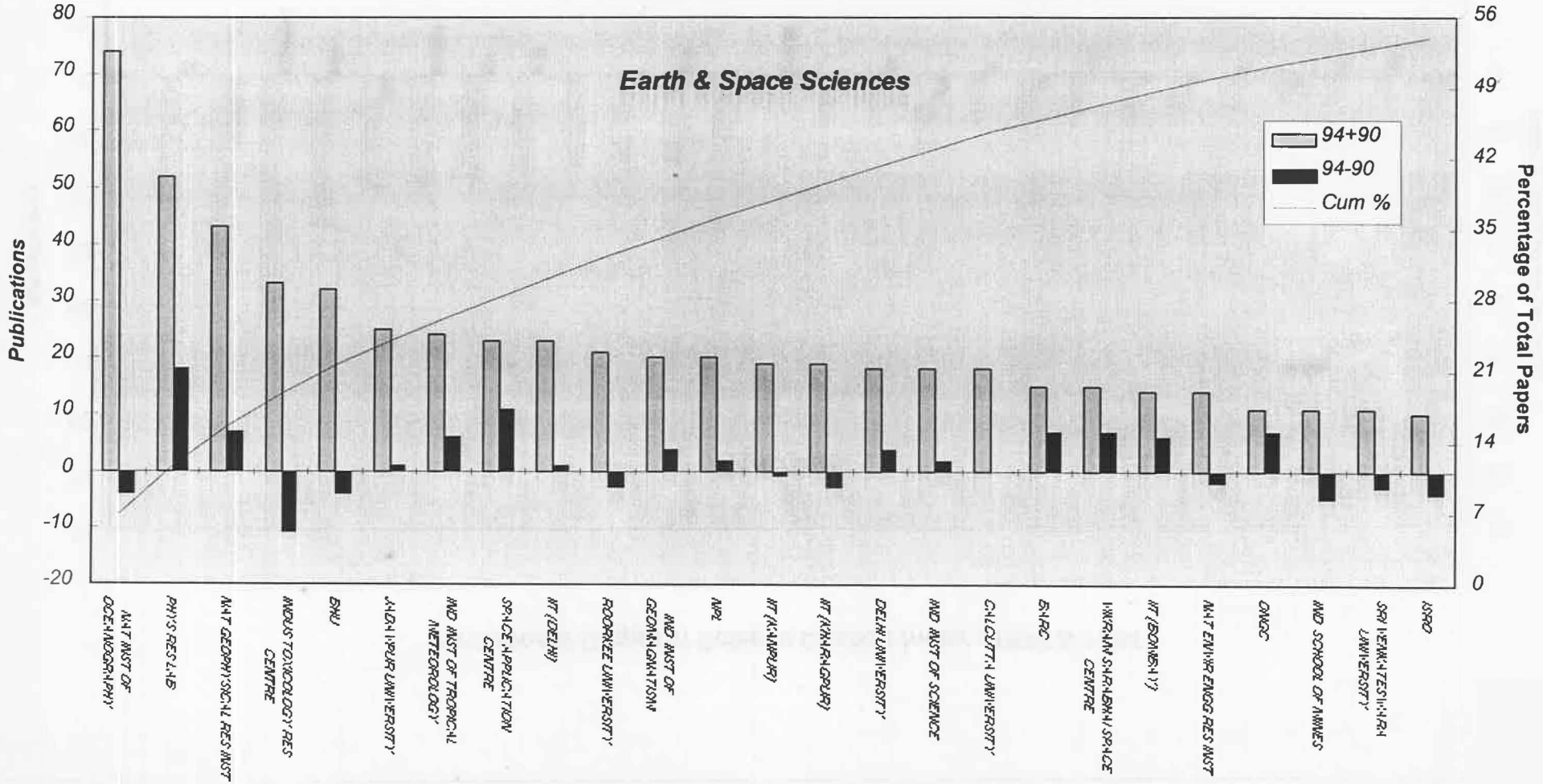
Institutional Output in Science Citation Index : 1990 & 1994



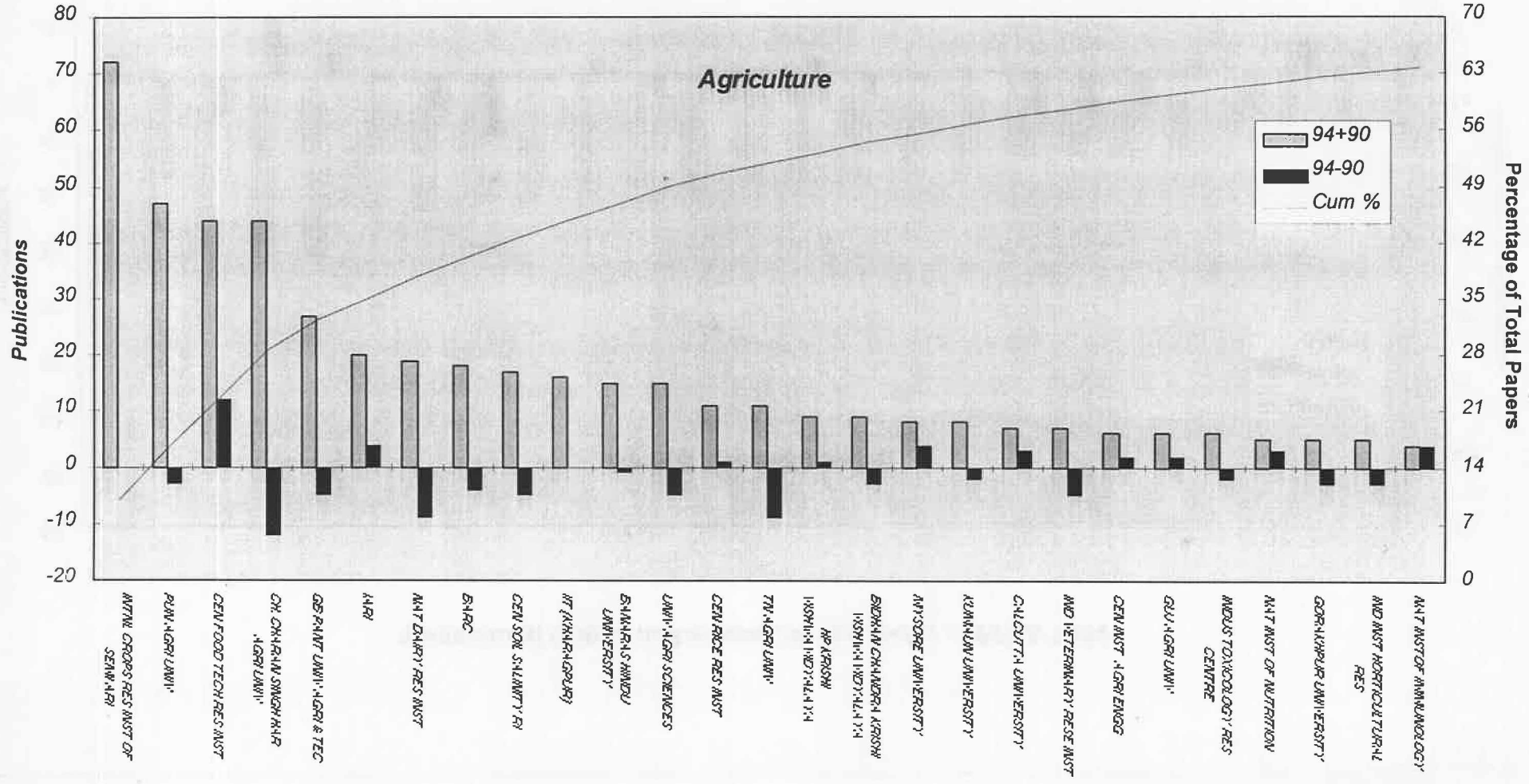
Institutional Output in Science Citation Index : 1990 & 1994



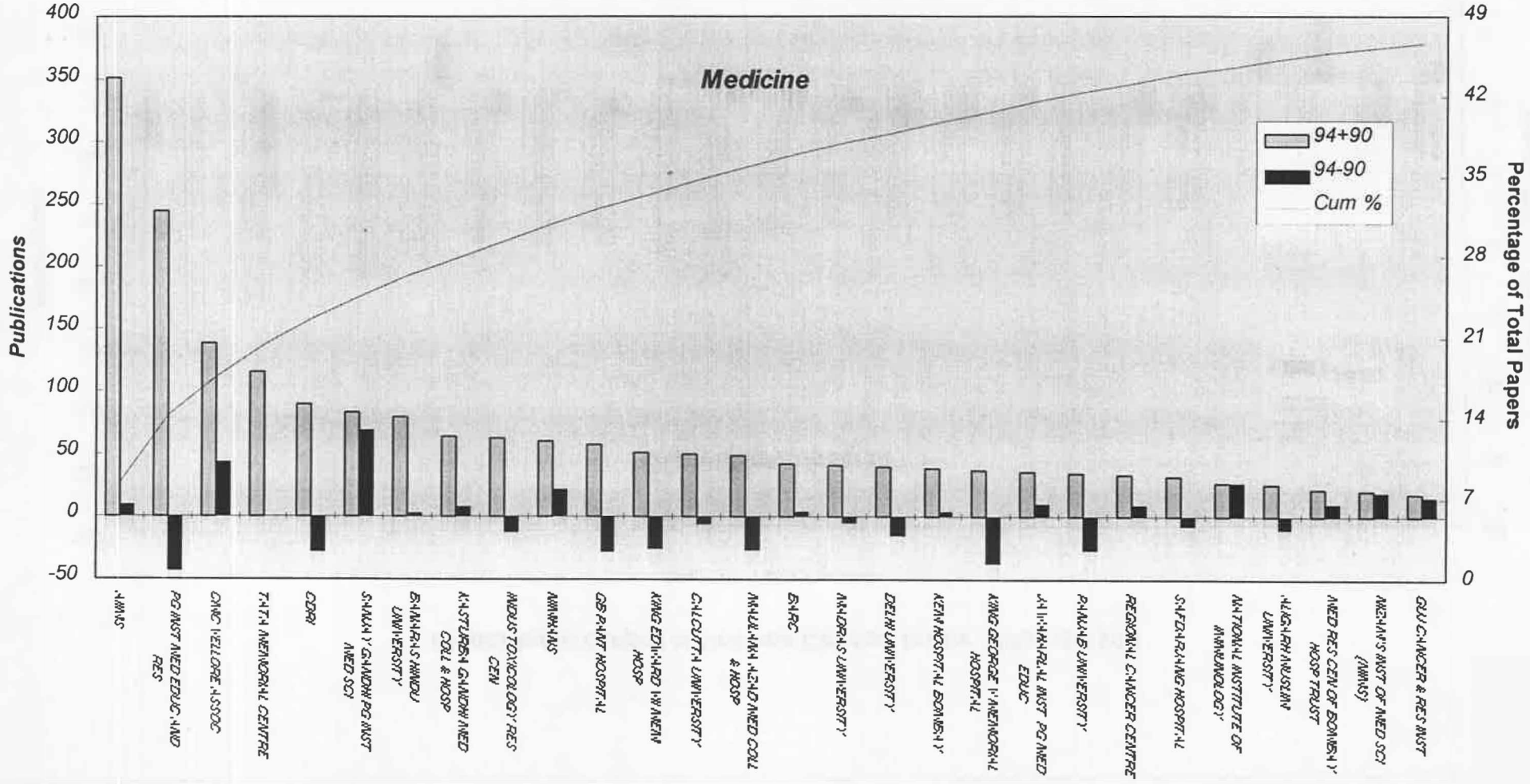
Institutional Output in Science Citation Index : 1990 & 1994



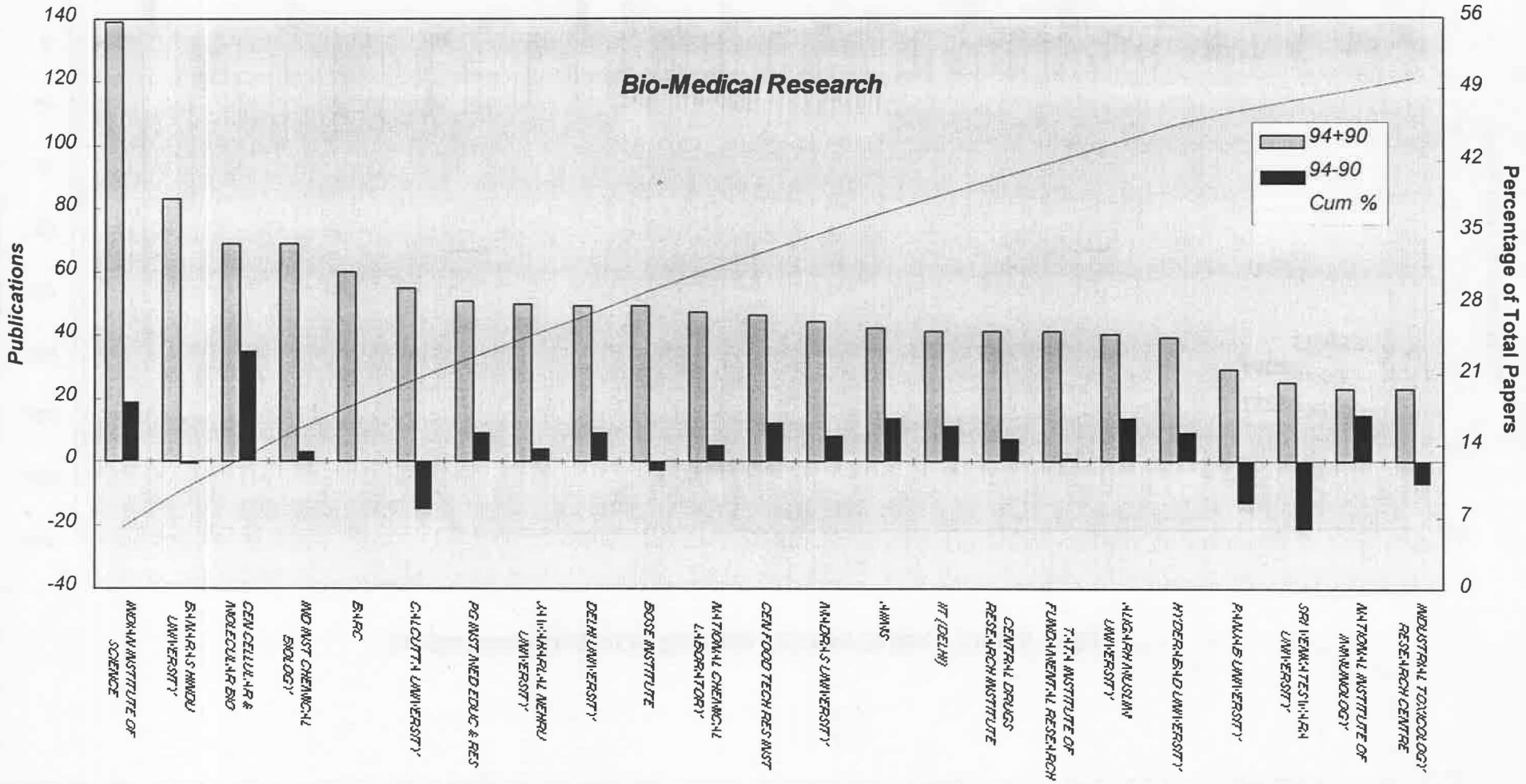
Institutional Output in Science Citation Index : 1990 & 1994



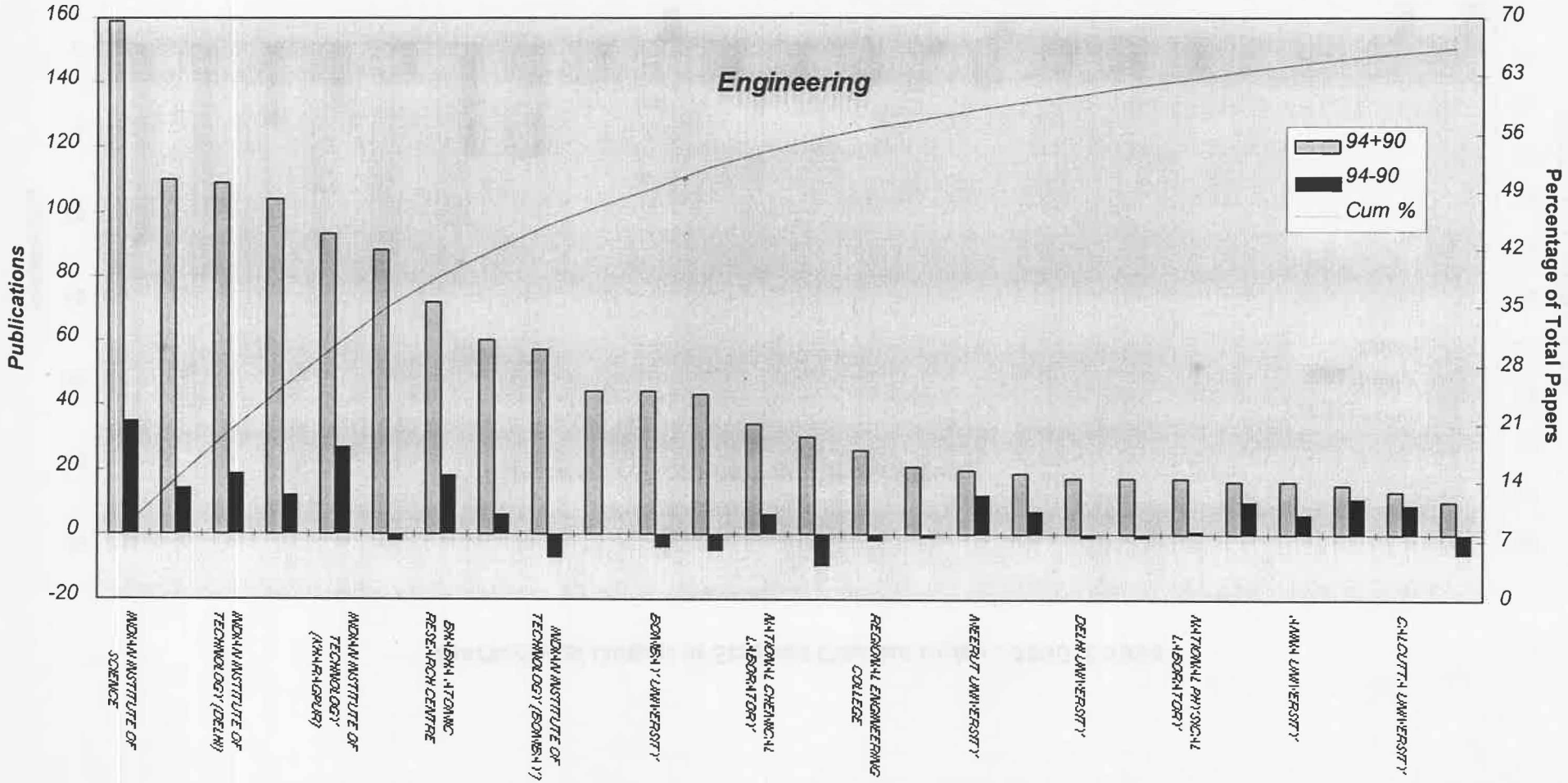
Institutional Output in Science Citation Index : 1990 & 1994

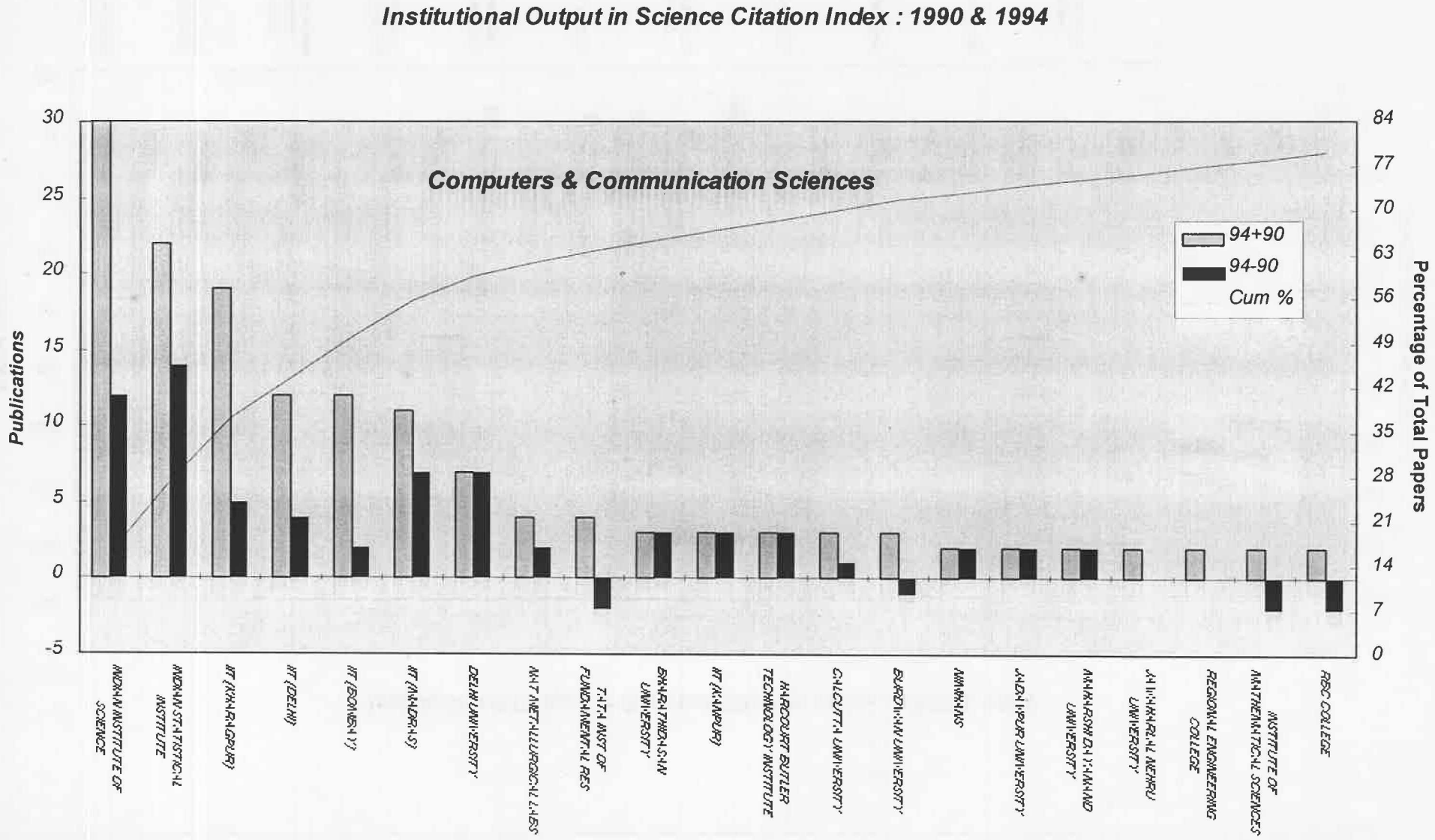


Institutional Output in Science Citation Index : 1990 & 1994

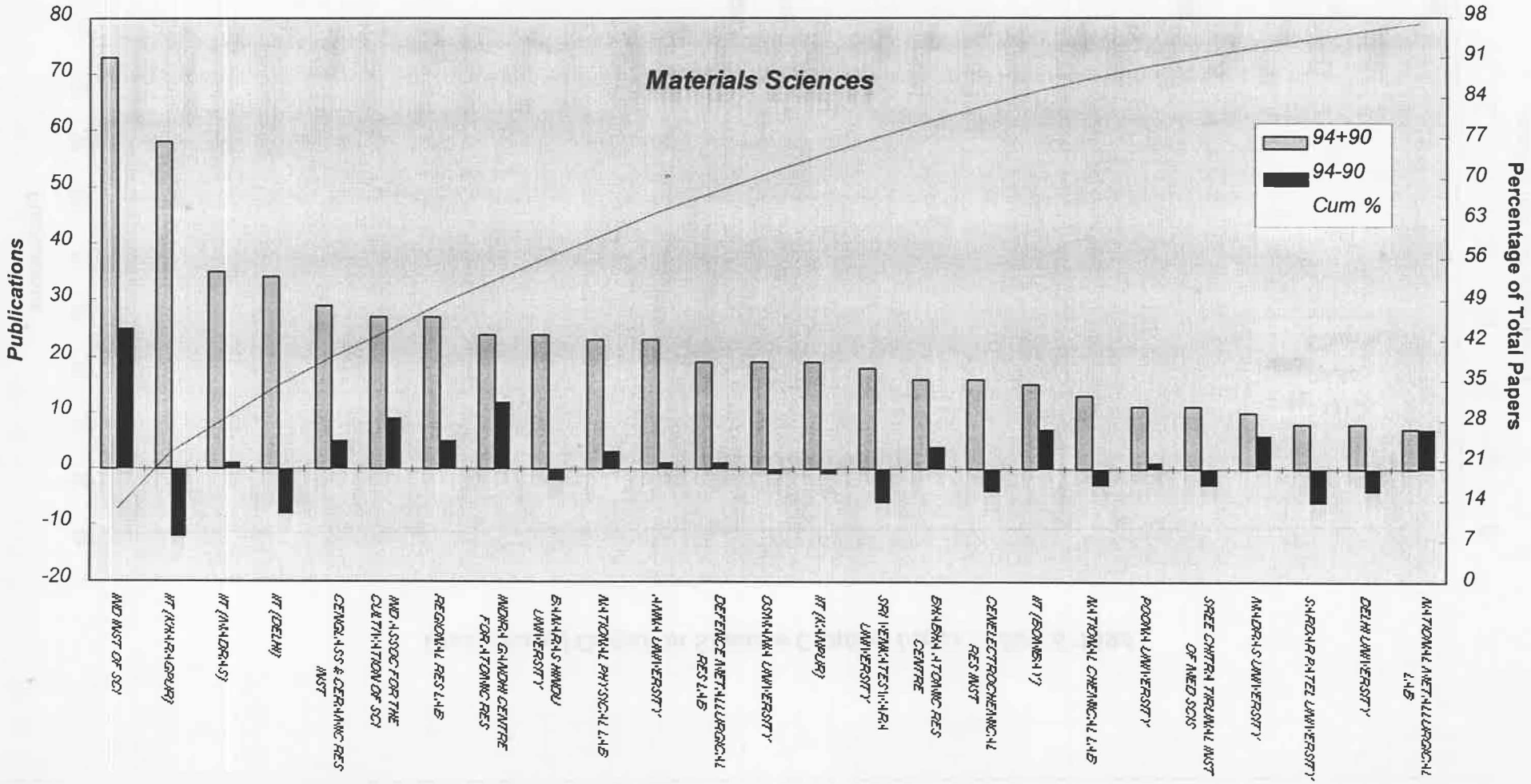


Institutional Output in Science Citation Index : 1990 & 1994

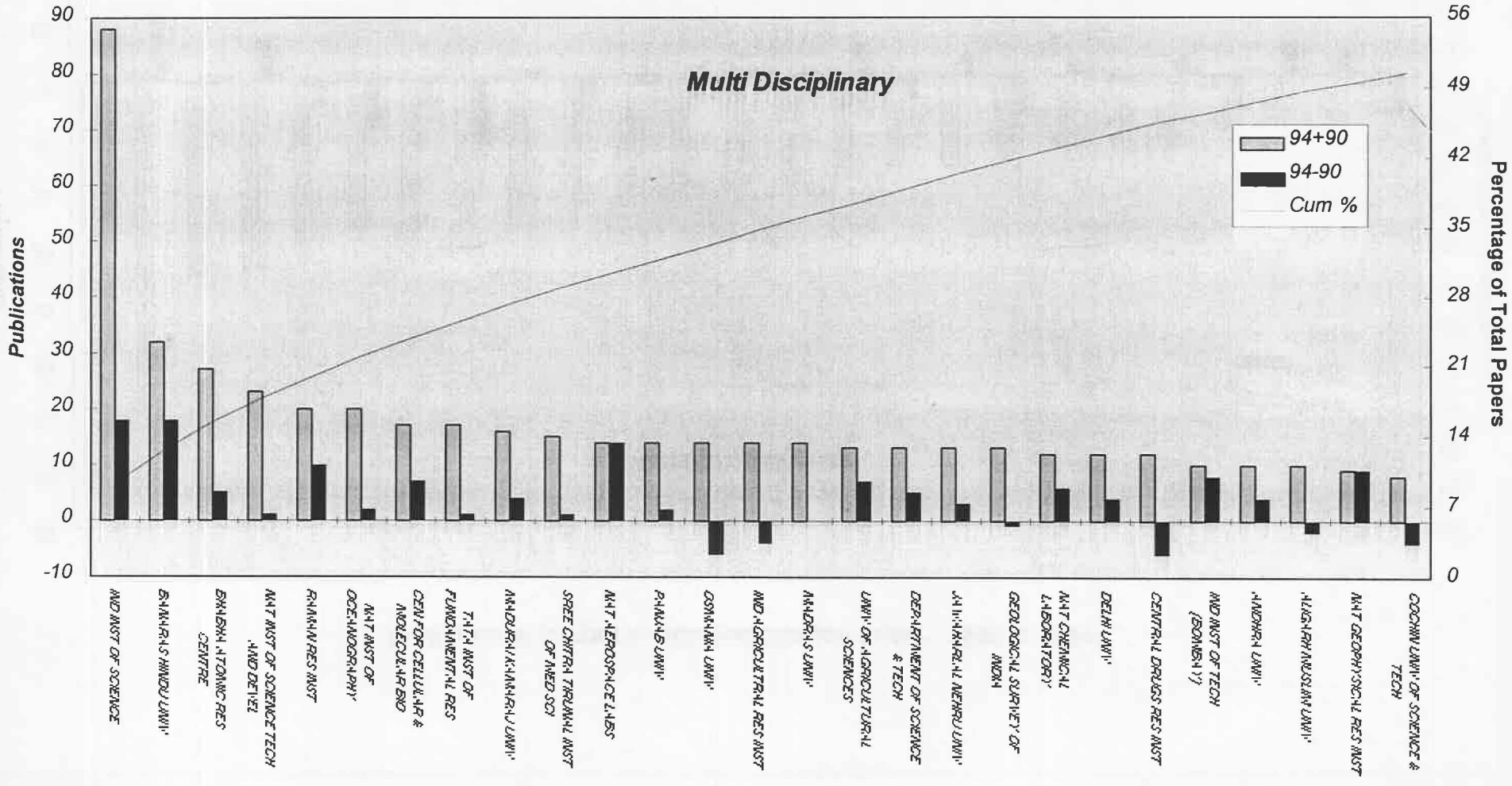



Institutional Output in Science Citation Index : 1990 & 1994
Computers & Communication Sciences
Publications
Percentage of Total Papers
94+90
94-90
Cum %
30
25
20
15
10
5
0
-5
84
77
70
63
56
49
42
35
28
21
14
7
0
INDIAN INSTITUTE OF SCIENCE
INDIAN STATISTICAL INSTITUTE
IIT (KHARAGPUR)
IIT (DELHI)
IIT (BOMBAY)
IIT (MADRAS)
DELHI UNIVERSITY
NAT AERONAUTICAL LABS
TATA INST OF FUNDAMENTAL RES
BHARATHIDASAN UNIVERSITY
IIT (KANPUR)
KHARAGPUR BUTLER TECHNOLOGY INSTITUTE
CALCUTTA UNIVERSITY
BARODA M S UNIVERSITY
ANNAMALAI
JADAVPUR UNIVERSITY
MAHARASHTRA SHIVAJI UNIVERSITY
JAWAHARLAL NEHRU UNIVERSITY
REGIONAL ENGINEERING COLLEGE
INSTITUTE OF MATHEMATICAL SCIENCES
REC COLLEGE

Institutional Output in Science Citation Index : 1990 & 1994



Institutional Output in Science Citation Index : 1990 & 1994



9 Collaboration Patterns

The Science Citation Index records the addresses of all authors of a paper. This enables the extraction of both foreign and domestic collaboration patterns. Collaboration is a significant indicator of the nature of scientific activity. In the transition between 'little science' and 'big science' the nature of collaborative activity has changed to some extent from that between individual scientists to one mediated by organizations, or national and international bodies. Thus the number of authors and addresses or countries in a single paper may even exceed a hundred, - a phenomenon not seen in the last decade. While a detailed analysis of these aspects is beyond the scope of this study, one may nevertheless obtain some idea of the frequency of collaboration, collaborating partners, and the changes in both bi-lateral and multi-lateral collaborations in each discipline, within the four year period of our study. From the co-authorship data, it is possible to obtain information on

1. foreign collaboration
2. inter-state collaboration
3. inter-institutional collaboration
4. individual collaboration

In this study we have restricted our attention to the first two, reserving the others for another study.

9.1 Foreign Collaboration

Foreign collaboration patterns have been obtained from the country of the respective author addresses in the individual records. It gives an indication of the degree of internationalization in Indian science.

In this section, we have indicated the ***volume of collaborative papers***, frequency of collaboration with different countries, break up in the major disciplines, the frequency of *bilateral* (with one foreign country) and *multilateral collaboration* (more than one foreign country), and changes between 1990 and 1994. No comparison has been made of the extent of India's foreign collaboration with that of other countries. This aspect has already been covered in an earlier study on transnational linkages[8].

9.2 Main Features

Analysis of our data on India's joint publications with other countries in the SCI for 1990 and 1994 shows the following main features:

Increase in Foreign collaboration : Out of a total of 10103 papers in 1990, 1334 papers or about 13.2 percent were written in collaboration with at least one author with a foreign address. In 1994, the number increased to 2111 out of a total of 11314 papers, or about 18.7 percent. Collaboration has increased primarily with USA, France, Canada, UK, Australia, Japan, Germany and Italy.

Increase in the number of partner countries : India had joint publications with 70 countries in 1990. By 1994, the number of collaborating countries had increased to 93. The frequency of collaboration with different countries is indicated in Table 9.1. The most frequent collaboration is with the USA, Germany, England, (more than 100 papers each in 1990 and 1994)

Collaboration with the new countries : It is seen that collaborative work with a number of new partner countries has been initiated in 1994 while with certain other countries collaboration has stopped. (Table 9.1)

Table 9.1 : Frequency of India's foreign Collaboration in 1990 & 1994

S.No	COUNTRY	1990	1994
1	ARGENTINA	4	3
2	AUSTRALIA	31	59
3	AUSTRIA	5	14
4	BAHRAIN	4	1
5	BANGLADESH	7	15
6	BELGIUM	11	18
7	BRAZIL	7	21
8	BRUNEI	1	5
9	BULGARIA	7	7
10	CANADA	74	122
11	CHILE	3	8
12	CZECHOSLOVAKIA	4	1
13	DENMARK	7	9
14	EGYPT	3	7
15	ENGLAND	119	169
16	ETHIOPIA	2	3
17	GERMANIES	135*	204
18	FRANCE	52	109
19	GREECE	5	9
20	HONG-KONG	3	2
21	HUNGARY	14	15
22	IRAN	3	2
23	IRAQ	1	2
24	IRELAND	1	4
25	ISRAEL	3	8
26	ITALY	52	85
27	JAPAN	73	125
28	JORDAN	3	1
29	KENYA	1	6
30	LIBYA	2	3
31	MALAYSIA	1	7
32	MEXICO	5	6
33	NEPAL	1	3
34	NETHERLANDS	29	32
35	NIGERIA	11	10
36	NORTH-IRELAND	3	17
37	NORWAY	4	7
38	OMAN	1	3
39	PAKISTAN	3	4
40	PEOPLES-R-CHINA	19	22
41	PHILIPPINES	5	7
42	POLAND	6	14
43	ROMANIA	3	7
44	SAUDI-ARABIA	2	3
45	SCOTLAND	12	20
46	SINGAPORE	3	5
47	SOUTH-AFRICA	4	10
48	SPAIN	21	27
49	SWEDEN	20	31
50	SWITZERLAND	37	32
51	SYRIA	1	12
52	TAIWAN	2	10
53	THAILAND	4	8
54	TURKEY	2	3
55	USA	441	611
56	VIETNAM	1	1
57	WALES	9	7
58	ZAMBIA	1	2
59	AFGHANISTAN	1	
60	ARABIA	1	
61	BERMUDA	1	
62	INDONESIA	1	
63	KUWAIT	4	
64	PAPUA-N-GUINEA	2	
65	PORTUGAL	1	
66	ZIMBABWE	4	
67	YUGOSLAVIA	1	
68	USSR	25	
69	FINLAND	5	
70	ALGERIA		1
71	ARMENIA		3
72	BYELARUS		2
73	COLOMBIA		6
74	CONGO		2
75	COSTA-RICA		1
76	CYPRUS		4
77	CZECH-REPUBLIC		4
78	FINLAND		14
79	GHANA		1
80	JAMAICA		1
81	KAZAKHSTAN		3
82	LEBANON		1
83	LESOTHO		1
84	LUXEMBOURG		1
85	MAURITIUS		1
86	MONACO		1
87	MOROCCO		2
88	NEW-ZEALAND		11
89	REP-OF-GEORGIA		1
90	RUSSIA		52
91	SLOVAKIA		4
92	SLOVENIA		1
93	SOUTH-KOREA		12
94	SRI-LANKA		3
95	SUDAN		1
96	SURREY		1
97	TANZANIA		2
98	TUNISIA		3
99	U-ARAB-EMIRATES		7
100	UKRAINE		1
101	UZBEKISTAN		4
102	YEMEN		1

* *FRG - 126; GDR - 9*

9.3 Foreign Collaboration in the Major Disciplines

Foreign collaboration has increased as a proportion of total publications in every discipline except ***Computers*** and ***Engineering***. In Tables 9.2 we have shown the number of collaborative papers in the different disciplines with their respective partner countries.

The field with the highest proportion of papers with foreign collaboration in 1990 was ***Computers and Communication*** (~30%). In 1994, the highest proportion was in ***Mathematics***, about one third of all the papers being written with foreign collaboration.

The areas in which the highest number of internationally co-authored papers were published were ***Physics, Clinical Medicine, Chemistry and Biomedical Research*** in both years (Table 9.2)

As a proportion of total output, Physics, followed by ***Mathematics*** and ***Computers*** are the areas of high foreign collaboration in 1994. The order has been reversed since 1990. (Table 9.-2a,b)

Average Impact Factor of papers written in collaboration with an author from a foreign country is higher (2.06) as compared to the national average (1.33). The differences in IF ratings of papers in collaboration with different countries has not been examined in this study.

The change in foreign collaboration in different disciplines in the period 1990 to 1994 are shown in Fig.9.1a and in the Change Matrix, Table 9.2c for a set of selected countries. Collaboration has increased markedly with France (109.6%), Australia (90%), Japan (71%) and Belgium, Canada, Germany, Italy (all > 60%).

Table 9.2a: NUMBER OF INDIAN PAPERS CO-AUTHORED WITH FOREIGN COLLABORATERS : 1994

COUNTRY	CODE	CHEM	PHYS	MEDI.	BIOMED	ENGG	BIO	MULTI	EARTH	AGRI	MATER.	MATHS	COMP.	TOTAL	% of total
PAPERS		2480	2438	1761	1150	912	556	551	504	284	376	189	113	11314	
USA	USA	71	191	99	79	36	36	16	29	8	13	19	14	611	28.94%
GERMANY	DEU	26	93	22	18	10	9	7	8	3	4	3	1	204	9.66%
ENGLAND	UKD	18	48	46	19	3	10		8	6	8	2	1	169	8.01%
JAPAN	JPN	18	35	16	21	3	8	5	10	2	4	2	1	125	5.92%
CANADA	CAN	8	44	14	11	9	8	1	8	1	1	14	3	122	5.78%
FRANCE	FRA	15	58	11	6		6	2	8	1	4			109	5.16%
ITALY	ITA	16	45	3	5	5	2	1	1		2	5		85	4.03%
AUSTRALIA	AUS	9	11	14	2	5	5	1	1	9		2		59	2.79%
RUSSIA	SUN	4	28	2	4			1	13					52	2.46%
NETHERLANDS	NLD	2	14	4	5	2			1	3		1		32	1.52%
SWITZERLAND	CHE	5	14	8	3	1						1		32	1.52%
SWEDEN	SWE	3	12	6	5	3			1	1				31	1.47%
SPAIN	ESP	1	17	3	2		1		1		2			27	1.28%
BRAZIL	BRA		17	2	1		1							21	0.99%
PEOPLES-R-CHINA	PRC		13	4	2		2							21	0.99%
SCOTLAND		4	5	5	3	1	1			1				20	0.95%
BELGIUM	BEL		6	5	3		3		1					18	0.85%
NORTH-IRELAND		1	12		4									17	0.81%
BANGLADESH	CIK	1	3	3	4	2	1					1		15	0.71%
HUNGARY	HUN	3	5	1	2	2						1	1	15	0.71%
AUSTRIA	AUT	4	4	3	1	1	1							14	0.66%
FINLAND	FIN	2	8	2				1	1					14	0.66%
POLAND	POL		7	3	1		3							14	0.66%
SOUTH-KOREA	KOR	1	6	2					1		1	1		12	0.57%
SYRIA	SYR						8	1		3				12	0.57%
NEW-ZEALAND	NZL	1	5			2	1	1	1					11	0.52%
NIGERIA	NGA	2	1	4	1	1							1	10	0.47%
SOUTH-AFRICA	ZAF		5	4	1									10	0.47%
TAIWAN	TWN	1	3	2	3	1								10	0.47%
OTHERS		12	74	55	14	11	24	3	7	10	2	2	5	219	10.37%
TOTAL		228	782	343	220	98	130	40	100	48	41	54	27	2111	
% FOREIGN COLLAB.		9.2%	32.1%	19.5%	19.1%	10.7%	23.4%	7.3%	19.8%	16.9%	10.9%	28.6%	23.9%	18.7%	
AVG. IMPACT FACTOR		2.059													

Table 9.2b: FOREIGN COLLABORATION IN VARIOUS DISCIPLINES (NO. OF PAPERS : 1990)

COUNTRY	CODE	*CHEM*	*PHYS*	*MEDICINE*	*BIOMED*	*ENGG*	*BIO*	*MULTI*	*EARTH*	*AGRI*	*MATER.*	*MATHS*	*COMP.*	*TOTAL*	*% of total*
PAPERS		2359	2189	1676	879	705	565	416	388	363	340	168	51	10099	
USA	USA	68	137	52	50	27	20	9	23	15	14	16	10	441	33.06%
FED-REP-GER	DEU	12	56	10	16	7	7	2	4	5	3	3	1	126	9.45%
ENGLAND	UKD	11	29	37	5	8	10		6	4	6	3		119	8.92%
CANADA	CAN	11	27	4	3	9	6		6		1	4	3	74	5.55%
JAPAN	JPN	16	18	5	2	5	11	1	10	1	3	1		73	5.47%
FRANCE	FRA	6	26	4	4	1	4	1	2	1		2	1	52	3.90%
ITALY	ITA	1	42	2	2	2			2	1				52	3.90%
SWITZERLAND	CHE	1	21	8		4				1		2		37	2.77%
AUSTRALIA	AUS	7	9	2		2	3	1	3	2		2		31	2.32%
NETHERLANDS	NLD	1	16	2	2		1		1		1	5		29	2.17%
USSR	SUN	5	14		1			1	3			1		25	1.87%
SPAIN	ESP	4	10	3							3	1		21	1.57%
SWEDEN	SWE		7	9	1		1		1	1				20	1.50%
PEOPLES-R-CHINA	PRC	2	13	1		1					2			19	1.42%
HUNGARY	HUN	4	8			1		1						14	1.05%
SCOTLAND			8		2		1					1		12	0.90%
BELGIUM	BEL	1	4	1			2	1	1			1		11	0.82%
NIGERIA	NGA	1	1	2			1			6				11	0.82%
OTHERS		14	54	27	9	16	11	4	10	10	2	8	2	167	12.52%
TOTAL		165	500	169	97	83	78	21	72	47	35	50	17	1334	
% FOREIGN COLLAB.		7.0%	22.8%	10.1%	11.0%	11.8%	13.8%	5.0%	18.6%	12.9%	10.3%	29.8%	33.3%	13.2%	
AVG. IMPACT FACTOR		1.920													

Table 9.2c Change Matrix for International Collaboration (1994-1990)

COUNTRY	CODE	CHEM	PHYS	MEDI.	BIOMED	ENGG	BIO	MULTI	EARTH	AGRI	MATER.	MATHS	COMP.	TOTAL	% CHANGE
PAPERS		121	249	85	271	207	-9	135	116	-79	36	21	62	1215	12.03%
AUSTRALIA	AUS	2	2	12	2	3	2	0	-2	7		0		28	90.32%
BELGIUM	BEL	-1	2	4	3		1	-1	0			-1		7	63.64%
CANADA	CAN	-3	17	10	8	0	2	1	2	1	0	10	0	48	64.86%
ENGLAND	UKD	7	19	9	14	-5	0		2	2	2	-1	1	50	42.02%
FRANCE	FRA	9	30	7	2	-1	2	1	6	0	4	-2	-1	57	109.62%
GERMANY	DEU	14	37	12	2	3	2	5	4	-2	1	0	0	78	61.90%
HUNGARY	HUN	-1	-3	1	2	1		-1				1	1	1	7.14%
ITALY	ITA	15	3	1	3	3	2	1	-1	-1	2	5		33	63.46%
JAPAN	JPN	2	17	11	19	-2	-3	4	0	1	1	1	1	52	71.23%
NETHERLANDS	NLD	1	-2	2	3	2	-1		0	3	-1	-4		3	10.34%
NIGERIA	NGA	1	0	2	1	1	-1			-6			1	-1	-9.09%
PEOPLES-R-CHINA	PRC	-2	0	3	2	-1	2				-2			2	10.53%
SPAIN	ESP	-3	7	0	2		1		1		-1	-1		6	28.57%
SWEDEN	SWE	3	5	-3	4	3	-1		0	0				11	55.00%
SWITZERLAND	CHE	4	-7	0	3	-3				-1		-1		-5	-13.51%
USA	USA	3	54	47	29	9	16	7	6	-7	-1	3	4	170	38.55%
OTHERS		-2	20	28	5	-5	13	-1	-3	0	0	-6	3	52	31.14%
TOTAL		63	282	174	123	15	52	19	28	1	6	4	10	777	58.25%
% OF TOTAL F C		2.20%	9.23%	9.39%	8.10%	-1.03%	9.58%	2.21%	1.28%	3.95%	0.61%	-1.19%	-9.44%	5.45%	

9.3.1 Country of Collaboration:

The frequency of collaboration with different countries varies with the discipline. In Table 9.3 we have shown the partner countries with the largest number of collaboration, by field of activity.

Table 9.3a -Countries collaborating with India in different Disciplines (1994)

Discipline	***Countries with high collaboration***
Mathematics	USA, Canada
Physics	USA, Germany, France, England, Italy, Canada, Japan, Spain, Brazil, Russia, Netherlands, China, Ireland
Chemistry	USA, Germany, UK
Biology	USA, England, Germany
Agriculture	Australia, USA, UK
Earth & Space Science	USA, Russia, Japan
Clinical Medicine	USA, UK, Germany
Biomedical Research	USA, Japan, England, Germany
Engineering & Technology	USA, Germany, Canada
Materials Science	USA, England
Computers	USA, Canada
Multidisciplinary	USA, Germany, Japan

Collaboration with the Third World : It is seen that collaborative work with a number of partner countries including those from the third world has been initiated by 1994.

The interaction level with some of the countries of the South Asia region are shown below

Table 9.3b Collaboration with South Asian Countries

Country	1990	1994
Australia	31	59
Bangladesh	7	15
Hong Kong	3	2
Malaysia	1	7
Nepal	1	3
Pakistan	3	4
People's rep China	19	21
Philippines	5	7
Singapore	3	5
Thailand	4	8
Indonesia	1	0
Vietnam	1	1
Papua New Guinea	2	0
Mauritius	0	1
South Korea	0	12
Sri Lanka	0	3
Total	81	168

We find that our co-operation with South Asian countries has doubled in four years.

9.3.2 Bilateral and Multilateral Collaboration :

We expect that there are organizational differences between collaborative efforts between authors in two countries which are likely to be based on individual initiative, and those involving several countries which may be the result of institutional or international initiatives. Thus the number of bilateral or multilateral collaborations may be indicative of these kinds of research co-operation.

The actual number of bilateral collaborations has increased in every discipline. The change in the number of bilateral collaborations between 1990 and 1994 has been highest in Physics, while the largest change in multilateral collaborations has been in Biology, Earth & Space Sciences, Engineering and Technology and Materials Sciences (Fig-9.1b, Table 9.4)

Table 9.4: Bilateral and Multi-lateral Collaborations in the Major Disciplines

Disciplines	*Bilateral '90*	*Bilateral '94*	*Multilateral '90*	*Multilateral '94*
Mathematics	34	42	6	6
Physics	254	409	66	105
Chemistry	139	192	12	18
Biology	71	74	2	19
Earth & Space Sc	50	63	6	11
Agriculture	36	38	5	5
Clinical Medicine	116	180	16	40
Biomedical Res.	87	148	4	27
Engg. & Tech.	67	86	7	6
Computers& Co	12	23	2	2
Mater. Sci	25	35	5	3
Multidisciplinary	18	29	1	4
Total	909	1319	132	246

Fig 9.1a Foreign Collaboration in Major disciplines as a Percentage of Output

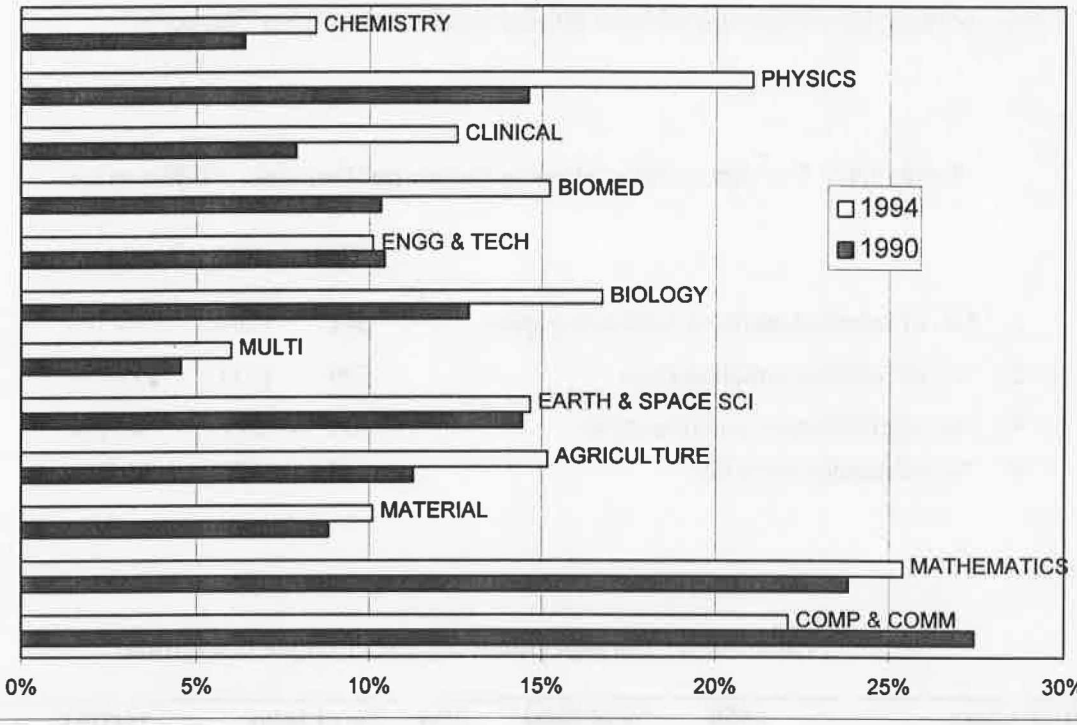
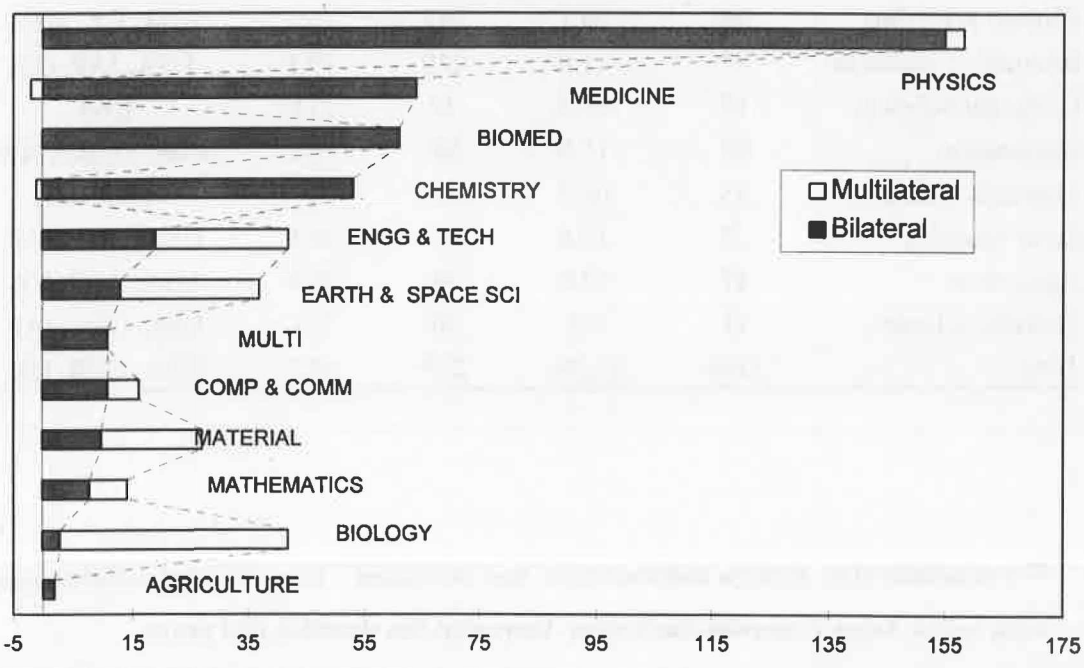


Fig 9.1b -Change in the No. of Bi-lateral and Multi-lateral Collaborations (1990 : 1994)



We reproduce here a relevant table on foreign collaboration from Chapter. 1

Table 9.4 a :Foreign collaboration in Indian publications An Overview

	1990	1994	%change
1. No. of internationally co-authored papers	641	1564	144.0%
2. No. of bilateral collaborations	509	1311	155.6%
3. No. of multilateral collaborations.	132	253	91.7%
4. No. of partner countries	70	93	32.86%

Table 9.4 b : Foreign collaboration in major disciplines.

Disciplines	1990	% of total output	1994	% of total output	partner countries '94
Mathematics	50	29.8	54	28.6	USA
Physics	500	22.8	782	32.1	USA, GER, UK
Chemistry	165	7.0	228	9.2	USA,GER
Biology	78	13.8	130	23.4	USA,UK
Clinical Medicine	169	10.1	343	19.5	USA, UK, GER
Biomedical Sciences	97	11.0	220	19.1	USA, JAP, UK
Computer Sciences	17	33..3	27	23.9	USA
Engineering	83	11.8	98	10.7	USA, GER, CAN
Materials Science	35	10..3	47	10..9	USA, UK
Earth Sciences	72	18.6	100	19.8	USA, RUS, JAP
Agriculture	47	12.9	48	16.9	USA, AUS, UK
Multidisciplinary	21	5.0	40	7.3	USA, GER, JAP
Total	1334	13.2%	219	18.7	USA, GER, UK

We conclude that foreign collaboration has increased , in particular collaboration with South Asian countries (including Australia) has doubled in 4 years.

9.4 Inter-State Collaboration

Inter-State collaboration patterns may be obtained from the co-authorship details in the individual records. We give a brief overview of the extent of inter-state collaboration in India in Table 9.5. The number of collaborative links between states is indicated in Tables 11.1 and 11.2. The network of links and changes between 1990 and 1994 have been analysed in Chapter 11 using the techniques of Network Analysis.

Table 9.5: Indian Publication Output and Interstate Co-operation in Science Fields

Disciplines	*No.of Articles (P)*	*Intn'l Collabs (I)*	*Inter-State Collabs (S)*	*India I/P % 1994*	*India S/P % 1994*	*World Levels of Intn'l Collab % 1990*
Mathematics	189	47	10	24.9	5.3	16.5
Physics	2438	496	232	20.3	9.5	12
Chemistry	2480	207	131	8.3	5.3	7.5
Biology	556	93	38	16.7	6.8	8
Earth & Space Sciences	504	78	67	15.5	13.3	14
Agriculture	284	43	12	15.1	4.2	-
Clinical Medicine	1761	223	94	12.7	5.3	7
Biomedical Research	1150	173	68	15.0	5.9	9.5
Engg & Technology	912	91	92	10.0	10.1	8
Computer Science	113	25	6	22.1	5.3	-
Materials Science	376	37	31	9.8	8.2	-
Multi Disciplinary	551	32	30	5.8	5.4	-
						-
Total	*11314*	*1545*	*811*	*13.7*	*7.2*	-

In every discipline the degree of international collaboration is higher than world averages. The highest level of international collaboration are in the fields of ***Mathematics***, ***Physics*** & ***Computer Science***. Every fourth paper has a foreign co-author in ***Mathematics***. The highest ***inter-state collaboration*** is in the areas of ***Earth & Space Science***, ***Engineering & Technology***, ***Physics*** (≥ 1 in 10 papers).

10 A Structural Analysis of Research Output

This chapter seeks to analyze: The structure of the system of multivariate relationships between states and fields of research performance for two time years: 1990 and 1994.

10.1 Structure of Research Output

10.1.1 1990 Data

Tables 10.1 and 10.2 present respectively the distribution of articles in 28 states and 11 research fields for 1990 and 1994. However, these data sets do not convey much information for the following reasons:

(i.) The sheer size of such data sets blur the overall structure and their hidden features[1].

(ii.) The raw counts of articles are confounded by the size of the states and scientific fields[2].

Moreover, these data sets have inbuilt redundancy due to the attribution of coauthored articles to the state of each other. There is also 'noise' in the data due to any misattribution of articles to the states (due to incomplete or wrong addresses of authors) and any misclassification of articles into scientific fields. It my be pointed out that the classification of articles is based on the *SCI* classification of journals into various disciplinary areas which have been aggregated into non– overlapping categories – 11 scientific fields plus one unidentified category 'multidisciplinary'. Hence, it is essential that the analytical schema for structural analysis should cope up with the problems of noise and redundancy in the data.

Table 10.1 : Publication Output for States in Different Disciplines - SCI Data 1990

STATES	MATHS	PHYS	CHEM	BIO	EARTH	AGRI	MED	BIOMED	ENGG	COMP	MTL	MULTI	TOT	AVG_IF
APR	13	156	306	56	42	50	51	91	60		39	36	900	1.204
ARN			5	1									6	0.676
ASM		23	24	3	2	3	2	4	2		1	1	65	1.007
BIH		24	14	10	14	7	11	9	24	1	5	4	123	0.799
CHD	3	25	39	8	5	4	171	46	5			10	316	1.301
DEL	19	217	134	50	38	14	363	94	78	6	39	55	1107	1.323
GOA		4	1	6	41	1	3	2	3			9	70	1.196
GUJ	5	56	82	14	34	9	36	20	2		12	13	283	1.203
HAR	1	24	70	20	6	53	24	17	9		1	7	232	0.792
HIM	1	8	8	9	1	11	16	6	2			4	66	1.028
J&K		10	14	14	2	2	20	13	1			5	81	1.330
KAR	27	257	163	37	18	39	98	110	85	12	32	78	956	1.266
KER	2	49	70	24	15	13	48	12	15	1	26	25	300	0.955
MAP	1	45	65	12	9	4	28	21	7		2	8	202	0.893
MAH	41	424	427	32	39	26	303	109	116	10	39	41	1607	1.553
MAN		19	4	2		1		2			1		29	0.786
MEG	1	24	29	12	2	1	1	1	1			3	75	1.199
MIZ			2									1	3	0.335
ORI	1	54	51	14	6	7	9	11	12		4	2	171	1.197
PON	1	5	10	5			29	6	1		1	1	59	0.663
PNJ	3	31	42	17	1	27	33	13	4		2	5	178	0.864
RAJ	3	52	81	16	6	7	31	5	20		3	10	234	1.007
TAM	11	216	152	37	10	21	153	54	94	9	50	34	841	1.217
TRI	1		1	2									4	0.550
UPR	16	249	354	128	95	65	248	131	156		42	57	1541	1.024
WBN	25	385	283	63	44	18	91	134	77	16	62	22	1220	1.262
TOTAL	175	2357	2431	592	430	383	1769	911	774	55	361	431	10669	1.2160

*- *Redundancy Factor = 5.60*

Table 10.2 : Publication Output for States in Different Disciplines SCI Data 1994

STATE	MATHS	PHYS	CHEM	BIO	EARTH	AGRI	MEDICINE	BIOMED	ENGG	COMP	MTL	MULTI	TOT	TOTAV_IF
AND		1	1	2	2		7		1				14	0.587
APR	4	174	261	82	65	46	90	123	61	3	39	45	993	1.481
ARN		2							2				4	1.986
ASM	2	16	26	4	3	3	4	9	6		1	3	77	0.709
BIH	1	17	10	7	12	2	11	11	27	3	11	7	119	0.972
CHD	3	38	39	3	7	1	119	54	5			12	281	1.587
DEL	39	251	142	69	56	23	362	157	95	16	37	65	1312	1.544
GOA	2	1	6	12	34		5	3	4			12	79	1.053
GUJ	2	90	107	10	66	6	53	21	16		6	15	392	1.268
HAR		23	78	25	9	21	28	16	15	2	3	9	229	0.866
HIM	2	9	8	11	1	8	1	4	1		1	1	47	0.784
J_K		17	6	4	9	2	16	6			4	4	68	0.877
KAR	17	278	223	36	31	49	127	165	134	22	59	134	1275	1.467
KER	4	45	86	19	25	8	62	22	28		24	17	340	1.118
MAP	3	97	69	14	11	6	42	36	20	1	10	11	320	1.1
MAH	43	533	509	45	71	11	269	142	144	13	45	79	1904	1.574
MAN		7	4		2	1	4	2				1	21	0.6
MEG		24	24	7	2	2		9				3	71	0.999
MIZ		1					1						2	0.38
ORI	5	92	56	8	6	7	22	10	14		1	3	224	1.338
PON		3	10	6	4		34	5	1		1	1	65	1.689
PNJ	2	27	30	16	5	32	22	29	7		1	2	173	0.959
RAJ	2	45	57	12	3		35	8	10	2	5	7	186	1.203
SIK								1					1	0.517
TAM	23	227	239	55	22	14	213	94	127	13	66	51	1144	1.147
TRI		1	2	2	1	1						1	8	0.59
UPR	26	226	322	107	88	33	234	148	187	11	33	86	1501	1.177
WBN	23	455	306	41	47	22	114	145	104	34	61	21	1373	1.256
TOTAL	**203**	**2700**	**2621**	**597**	**582**	**298**	**1875**	**1220**	**1009**	**120**	**408**	**590**	**12223**	**1.333**

Redundancy Factor = 7.99

According to Engelsman & van Raan (1994), a cartographic approach to structural analysis not only reformats the data into a specific graphs representation (i.e. maps), it also accomplishes data reduction while retaining the essential information. Correspondence analysis is a high-performance cartographic technique, which can achieve appropriate data reduction, minimize the effects of redundancy, filter out noise within the data set and objectify correlations among the variables.

The structure of the system of the multivariate relationships between twenty four states and eleven scientific fields was analyzed through correspondence analysis, using the computer program SimCA. Four states (Arunachal, Andaman, Mizoram, Sikkim) which had many empty cells were excluded from the analysis. The field of *Computer Science,* for which there were many empty cells, was treated as a supplementary variable. Supplementary variables do not have any influence on the determination of factorial axes, but their coordinates and relative contributions to the eccentricities of the axes ($\cos^2\phi$) are computed by the program. As a result of correspondence analysis, each field in the high – dimensional space is projected into the low– dimensional subspace of 24 states whereas each state is projected into the low– dimensional subspace of eleven fields.

The chi – square statistic computed by program (χ^2 = 2767; d.f. = 207) is highly significant, which means that the association between states and research fields is not random.

The results of correspondence analysis are summarized in Tables 10.3 and 10.4.

Eigen values issued by the correspondence analysis indicate that the total inertia ($\Sigma\lambda_i$ = 0.272001) is large, indicating large variations in the amplitudes of profiles of states and fields.

The first three axes ϕ_1 – ϕ_3, indicating about 79% of the total variance (τ) in the multidimensional system, yield the most parsimonious representation of the data. The remaining axes, accounting for successively smaller amounts of variance, represent information of an idiosyncratic nature, which does not have much bearing on the basic

structure of the multidimensional system. The first two axes, accounting for about 60% of the total variance, represent the essential features of the system; the third axis accounting for 18.7% of the total variance provides complementary data for further analysis and elaboration. Figure 10.1 presents the two dimensional factorial map spanned by the first two factorial axes.

Factor ϕ_1: The first factorial axis, accounting for 34.2% of the total variance, represents the most important element of the structure of the multidimensional system.

On the cloud of fields, this factor is characterized by the polarity between *Clinical Medicine* and *Chemistry. Clinical Medicine* is almost entirely represented on this axis whereas *Chemistry* represented on the first and fourth axis.

The states projected on this axis can be classified into two clusters, depending upon the signs of their coordinates of projection.

Cluster 1: Chandigarh, Delhi, Pondicherry and J&K

Cluster 2: Andhra, Assam, Orissa and Meghalaya

Cluster 1 states, projected with positive coordinates, are correlated to *Clinical Medicine*, whereas *Cluster* 2 states, projected with negative coordinates, are correlated to *Chemistry*. This means that *Cluster* 1 states publish preferentially in *Clinical Medicine*, whereas *Cluster* 2 states publish preferentially in *Chemistry*.

Factor ϕ_2: This axis accounts for 24.8% of the total variance and constitutes the second most important element of the data structure. On the cloud of fields this factor is characterized by the polarity between *Agriculture*, *Biology* and *Earth & Space Science* on the one hand and *Physics* on the other.

The states projected on this axis can be classified into two clusters, depending upon the signs of their coordinates of projection.

Cluster 1: Goa, Haryana, UP and J&K

Cluster 2: Karnataka, Kerala, Maharashtra, West Bengal and Tamilnadu.

Table10.3
Contributions of explicative points to the composition of factorial axes (Ctr)* (Research output)

Cloud	*Explicative points with positive coordinates*	*Explicative points with negative coordinates*
	Axis 1 ($\lambda_1 = 0.090431$, $\tau_1 = 33.25\%$)	
Fields	Clinical Medicine (658)	Geosciences (173)
States	Chandigarh (313), Delhi (231), Pondicherry (43)	Andhra (95), Goa (124)
	Axis 2 ($\lambda_2 = 0.072721$, $\tau_2 = 26.74\%$)	
Fields	Physics (106),	Geosciences (709) Clinical Medicine (101)
States	Karnataka (37)	Goa (629), UP (39)
	Axis 3 ($\lambda_3 = 0.050833$, $\tau_3 = 18.69\%$)	
Fields	Physics (179)	Agriculture (616)
States	West Bengal (111)	Haryana (444), Himachal Pradesh (84), Punjab (146)

* Values are in permills

Table10.4
Contributions of explained points to the eccentricities of factorial axes ($cos^2\phi$)* (Research output).

Cloud	*Explicative points with positive coordinates*	*Explicative points with negative coordinates*
	Axis 1 ($\lambda_1 = 0.090431$, $\tau_1 = 33.25\%$)	
Fields	Clinical Medicine (871)	Chemistry (315)
States	Chandigarh (800), Delhi (830), Pondicherry (785)	Andhra (624), Assam (384), Gujarat (274) Meghalaya (277), Orissa (539)
	Axis 2 ($\lambda_2 = 0.072721$, $\tau_2 = 26.74\%$)	
Fields	Physics (353)	Geosciences (739)
States	Karnataka (319)	Goa (767), Gujarat (347), UP (333)
	Axis 3 ($\lambda_3 = 0.050833$, $\tau_3 = 18.69\%$)	
Fields	Physics (415) Computers (317)	Agriculture (778)
States	West Bengal (393)	Haryana (827), Himachal Pradesh (809), Punjab (871)

* Values are in permills

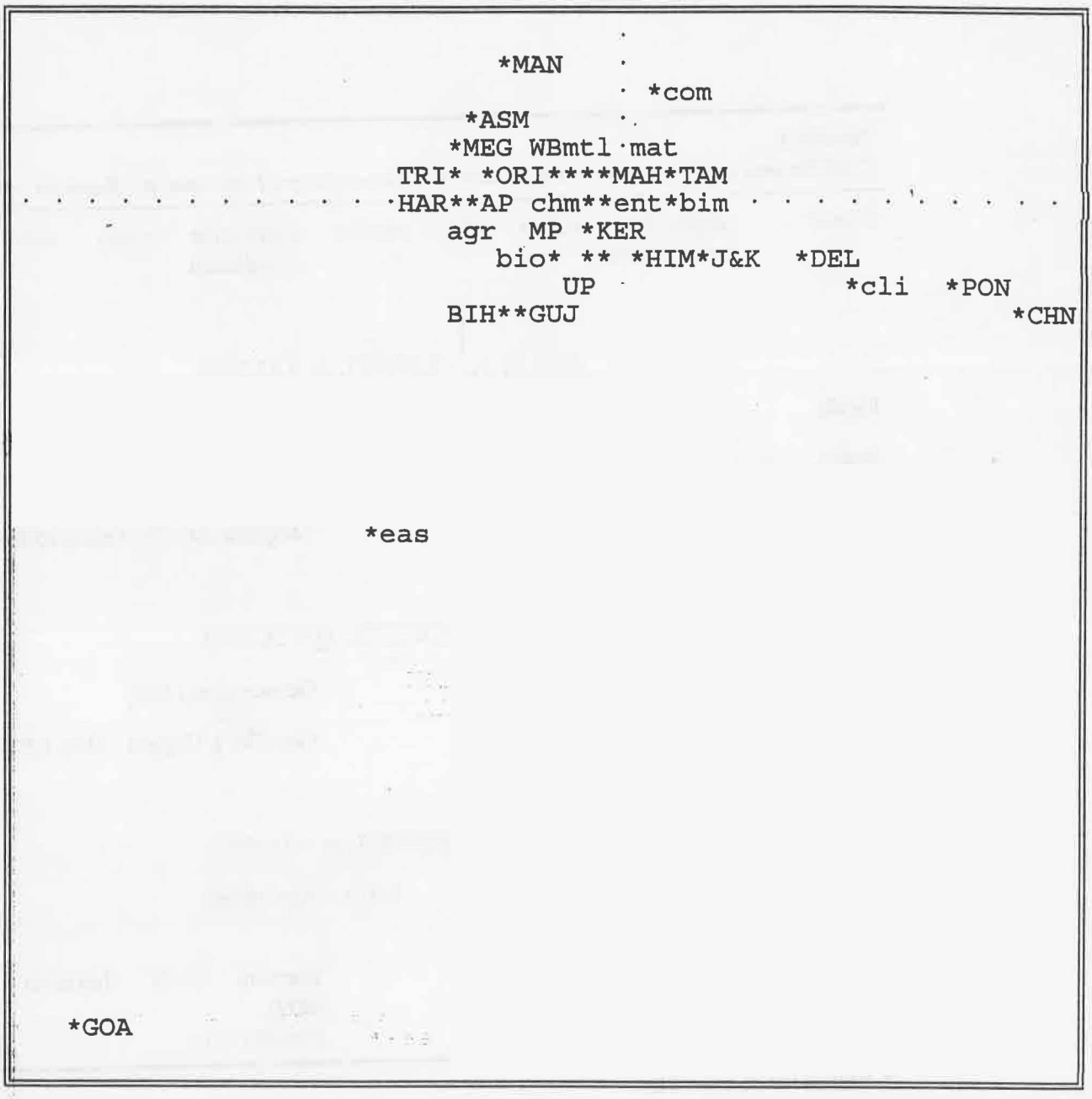


Fig. 10.1: Correspondence analysis map of research profile for 1990

Horizontal axis is dimension 1 with inertia = 0.0904 (33.2%)
Vertical axis is dimension 2 with inertia = 0.0727 (26.7%)
60.0% of total inertia is represented in the above map

Cluster 1 states, projected with positive coordinates, publish preferentially in *Biology*, *Agriculture*, and *Earth & Space Science*, whereas *Cluster* 2 states, projected with negative coordinates, publish preferentially in *Physics*.

Factor ϕ_3: This factorial axis accounts for 17.8% of the total variance in the multidimensional system. Figure 10.2 presents the two – dimensional factorial map spanned by ϕ_1 and ϕ_3 axes.

On the cloud of fields, this axis is characterized by the polarity between *Agriculture* and *Earth & Space Science*. These two fields are associated on the second axis, but they are opposed on the third axis. However, association or opposition on the third axis is less pronounced than that on the second axis, since the third axis accounts for less variance than the second.

On the cloud of states, this axis is characterized by the polarity between Haryana, Himachal and Punjab on the one hand, and Gujarat and Goa on the other. Haryana, Himachal and Punjab are correlated to *Agriculture*, whereas Gujarat and Goa are correlated to *Earth & Space Science*.

10.1.2 1994 Data

The data matrix for 1994 was submitted to the correspondence analysis algorithm. Four states (Arunachal, Andaman, Mizoram, Sikkim) which had many empty cells were excluded from the analysis. The field of *Computer Science,* for which there were many empty cells, was treated as a supplementary variable.

The chi – square statistic computed by program (χ^2 = 4675.51; d.f. = 207) is highly significant, which means that the association between states and research fields is not random.

The results of correspondence analysis are summarized in Tables 10.5 and 10.6.

Eigen values issued by the correspondence analysis indicate that the total inertia ($\Sigma\lambda_i$ = 0.203425) is large, indicating large variations in the amplitudes of profiles of states and fields.

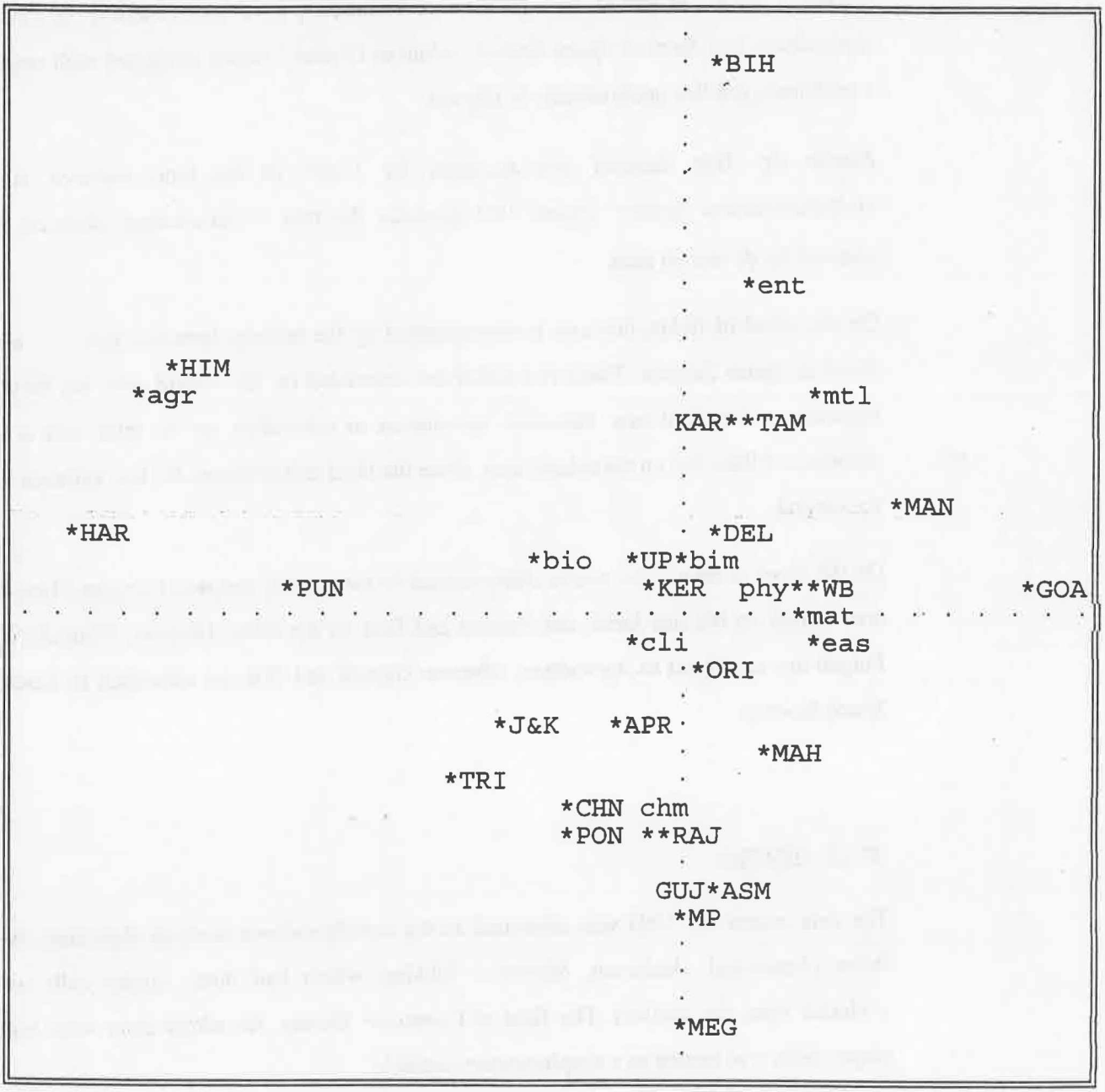


Fig. 10.2: Correspondence analysis map of research profiles for 199(

Horizontal axis is dimension 3 with inertia = 0.0508 (18.7%)
Vertical axis is dimension 4 with inertia = 0.0183 (6.7%)
25.4% of total inertia is represented in the above map

Table10.5
Contributions of explicative points to the composition of factorial axes (Ctr)* (Research output)

Cloud	*Explicative points with positive coordinates*	*Explicative points with negative coordinates*
	Axis 1 ($\lambda_1 = 0.055512$, $\tau_1 = 27.29\%$)	
Fields	Clinical Medicine (589)	Physics (190), Chemistry (119)
States	Chandigarh (207), Delhi (277), Pondicherry (96)	Maharashtra (45), Orissa (39), West Bengal (146)
	Axis 2 ($\lambda_2 = 0.054350$, $\tau_2 = 26.72\%$)	
Fields	Biology (166), Earth & Space Science (451), Agriculture (147)	Physics (103), Clinical Medicine (101)
States	Andhra (114), Goa (326), Gujarat (77), Haryana (60), Himachal (39), Punjab (62)	Chandigarh (58), Maharashtra (61), Tamilnadu (37)
	Axis 3 ($\lambda_3 = 0.039972$, $\tau_3 = 19.65\%$)	
Fields	Agriculture (461)	Earth & Space Science (336)
States	Himachal (75), Karnataka (54)	Goa (177), Gujarat (170)
	Axis 4 ($\lambda_4 = 0.020898$, $\tau_4 = 10.27\%$)	
Fields	Engineering & Technology (555), Materials (531)	—
States	Punjab (279), Assam (226)	Maharashtra (91)

* Values are in permills

Table10.6
Contributions of explained points to the eccentricities of factorial axes ($cos^2\phi$)* (Research output).

Cloud	*Explicative points with positive coordinates*	*Explicative points with negative coordinates*
	Axis 1 ($\lambda_1 = 0.055512$, $\tau_1 = 27.29\%$)	
Fields	Clinical Medicine (817)	Physics (463), Chemistry (430)
States	Chandigarh (622), Delhi (770), Pondicherry (817)	Assam (462), Madhya Pradesh (333), Meghalaya (469), Orissa (447), West Bengal (656)
	Axis 2 ($\lambda_2 = 0.054350$, $\tau_2 = 26.72\%$)	
Fields	Biology (552), Earth & Space Science (582), Agriculture	Physics (245)
States	Andhra (620),Goa(620), Gujarat (314), Haryana (371), Himachal (298), Tripura (684)	Maharashtra (285), Tamilnadu (321)
	Axis 3 ($\lambda_3 = 0.039972$, $\tau_3 = 19.65\%$)	
Fields	Agriculture (611)	Earth & Space Science (318)
States	Himachal (424), Karnataka (258)	Goa (267), Gujarat (509)
	Axis 4 ($\lambda_4 = 0.020898$, $\tau_4 = 10.27\%$)	
Fields	Engineering & Technology (866), Materials (243)	—
States	Punjab (636), Assam (798), Tamilnadu (392)	Maharashtra (314)

* Values are in permills

The first four factorial axes $\phi_1 - \phi_4$, indicating about 84% of the total variance (τ) in the multidimensional system, yield the most parsimonious representation of the data. The first two axes, accounting for about 54% of the total variance, represent the essential features of the system; the third and fourth axes respectively accounting for 19.65% and 10.27% of the total variance provides complementary data for further analysis and elaboration.

Figure 10.3 represents the two – dimensional factorial map constituted by ϕ_1 and ϕ_2 axes.

Factor ϕ_1: The first factorial axis, accounting for 27.3% of the total variance, represents the most important element of the structure of the multidimensional system.

On the cloud of fields, this factor is characterized by the polarity between *Clinical Medicine* on the one hand and *Physics* and *Chemistry* on the other. *Clinical Medicine* is almost entirely represented on this axis. *Clinical Medicine* projected with positive coordinate, whereas *Physics* and *Chemistry*

mistry are projected with negative coordinates.

The states projected on this axis can be classified into two clusters, depending upon the signs of their coordinates of projection.

Cluster 1: Chandigarh, Delhi and Pondicherry

Cluster 2: Maharashtra, Orissa, West Bengal, Assam, Madhya Pradesh and Meghalaya

Cluster 1 states, projected with positive coordinates, are correlated to *Clinical Medicine*, whereas *Cluster* 2 states, projected with negative coordinates, are correlated to *Chemistry / Physics*. This means that Cluster 1 states publish preferentially in *Clinical Medicine*, whereas *Cluster* 2 states publish preferentially in *Chemistry / Physics*; depending upon the proximities of these states to the poles of these two fields.

Factor ϕ_2: This axis accounts for 26.7% of the total variance and constitutes the second most important element of the data structure. On the cloud of fields this factor is characterized by the polarity between *Biology*, Agriculture, *Earth & Space Science* on the one hand and *Physics* on the other.

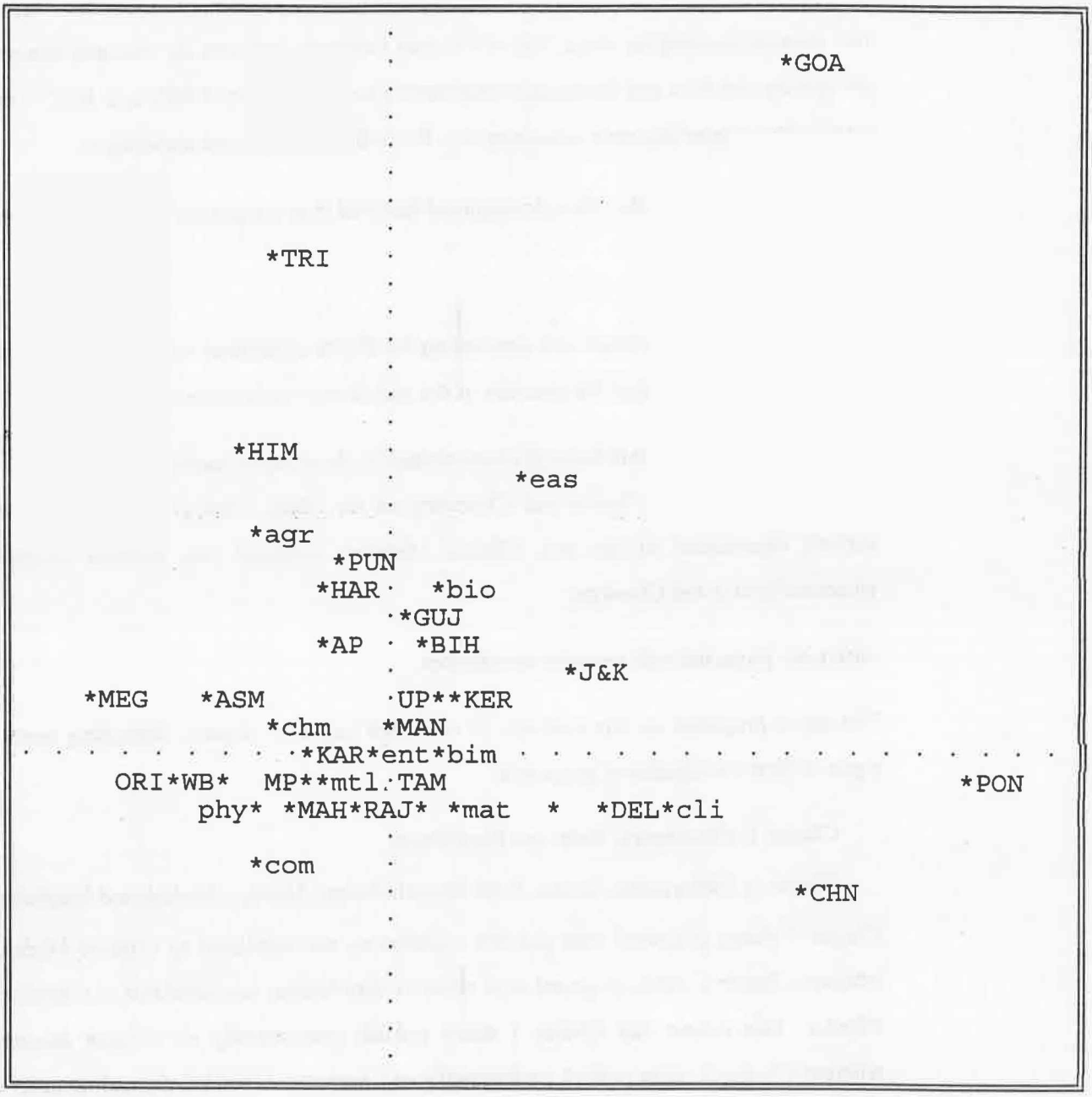


Fig. 10.3: Correspondence analysis map of research profile for 1994

Horizontal axis is dimension 1 with inertia = 0.0555 (27.3%)
Vertical axis is dimension 2 with inertia = 0.0544 (26.7%)
54.0% of total inertia is represented in the above map

The states projected on this axis can be classified into two clusters, depending upon the signs of their coordinates of projection.

Cluster 1: Andhra, Goa, Gujarat, Haryana, Himachal, Punjab and Tripura

Cluster 2: Maharashtra and Tamilnadu.

Cluster 1 states, projected with positive coordinates, publish preferentially in *Biology*, *Agriculture*, and *Earth & Space Science*, whereas *Cluster* 2 states, projected with negative coordinates, publish preferentially in *Physics*.

Factor ϕ_3: This factorial axis accounts for 19.7% of the total variance in the multidimensional system. Figure 10.4 presents the two – dimensional factorial map spanned by ϕ_1 and ϕ_3 axes.

On the cloud of fields, this axis is characterized by the polarity between *Agriculture* and *Earth & Space Science*. These two fields are associated on the second axis, but they are opposed on the third axis. However, association or opposition on the third axis is less pronounced than that on the second axis, since the third axis accounts for less variance than the second.

On the cloud of states, this axis is characterized by the polarity between Himachal and Karnataka on the one hand, and Gujarat and Goa on the other. Himachal and Karnataka publish preferentially in *Agriculture*, whereas Gujarat and Goa publish preferentially *Earth & Space Science*.

Factor ϕ_4: This factorial axis accounts for 19.3% of the total variance in the multidimensional system (Figure 10.4).

This is a unipolar factor controlled by *Engineering & Technology* and *Materials*. Tamilnadu, Punjab and Assam are projected on this axis with positive coordinates and are therefore correlated to these two fields. Maharashtra is projected on this axis with negative coordinates and is therefore anticorrelated to these fields.

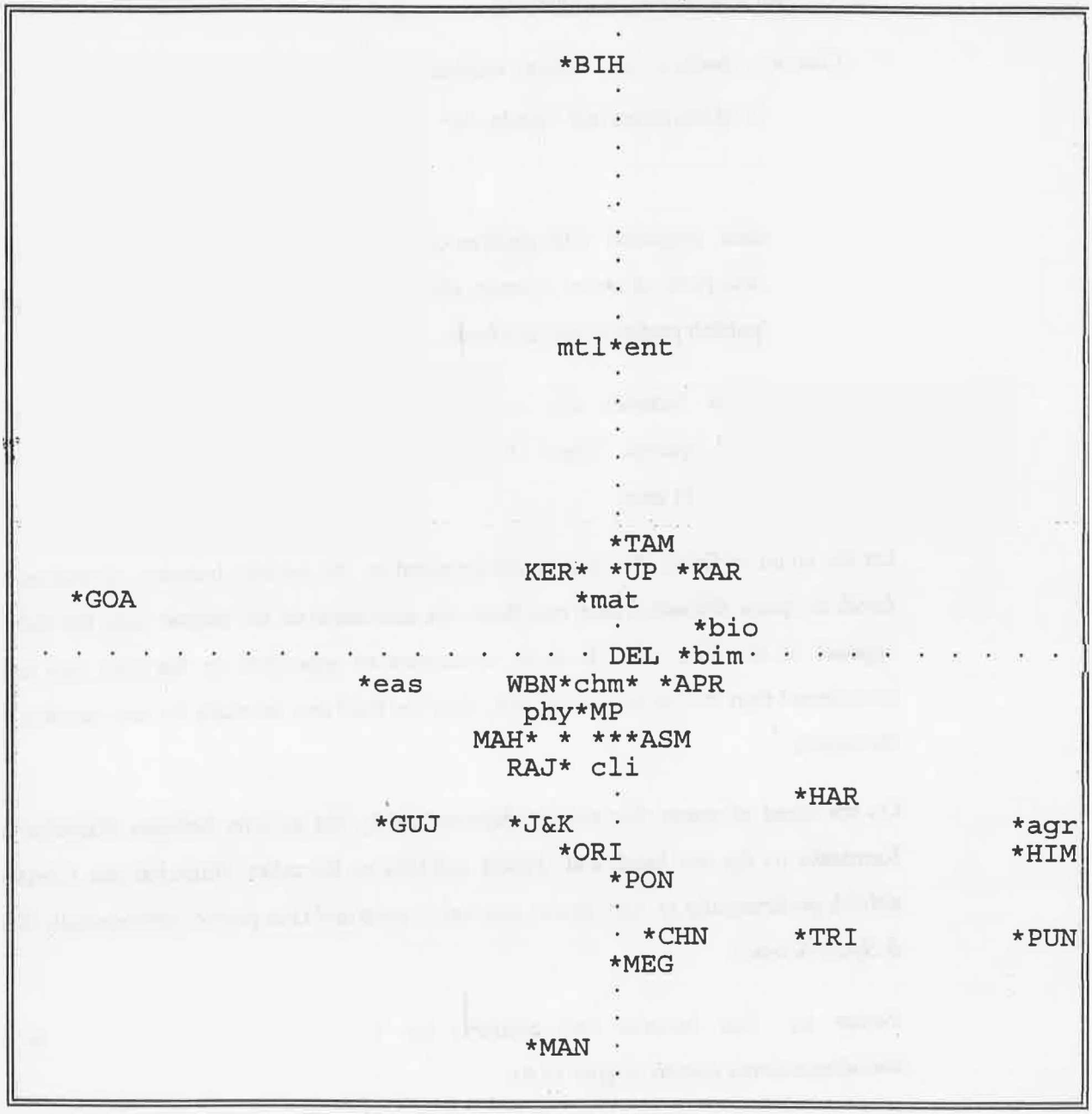


Fig. 10.4: Correspondence analysis map of research profiles for 1994

Horizontal axis is dimension 3 with inertia = 0.0400 (19.6%)
Vertical axis is dimension 4 with inertia = 0.0209 (10.3%)
29.9% of total inertia is represented in the above map

The complex structures of relationships of 24 states with eleven scientific fields (in which they publish and cooperate with other states) as revealed by the correspondence analysis of the data matrices are summarized in the *Infographic Maps* (Figures 10.5 and 10.6). Some keys for interpreting the *Infographic Maps* are given below:

In the *Infographic Map*, the significant factorial axes are displayed together, whereas in Correspondence Analysis, the factorial axes are displayed two at a time, orthogonal to each other. Hence, in the *Infographic Map*, the factorial axes cannot be displayed as orthogonal to each other.

In the factorial map, all countries and fields are located at different points, and inter – point distances have certain meaning. In the *Infographic Map*, only those countries and fields are displayed, which are correlated to the significant factorial axes. Both countries and fields are located at the poles of the factorial axes and inter – point distances have no meaning!

Countries and fields located at a given pole of a factorial axis are associated. This means that the countries have stronger preference for cooperation in the fields located at the proximate pole. These countries are anticorrelated to the fields located at the opposite pole of the factorial axis and *vice versa*. However, the correlations and anticorrelations along the first axis are stronger than those on the second axis, which in turn are stronger than those on the third axis, and so on. This is due to the reason that the first factorial axis explains greater variance than the second axis, which in turn explains greater variance than the third axis, and so on.

10.2 Comparisons of Structures of Research Output for 1990 and 1994 Data

The structures of research output for 1990 and 1994 data revealed by correspondence analysis are not concordant. There are important differences as well as similarities which are summarized below:

1. Total inertia of the configuration for 1990 data is greater than that for 1994 data, which means that interstate differences in research profiles are greater in 1990 than in 1994.

2. There are also differences in the composition of factorial axes on both the clouds (i.e. fields and states).

3. There are certain difference in the correlations of states and fields during these two time spans.

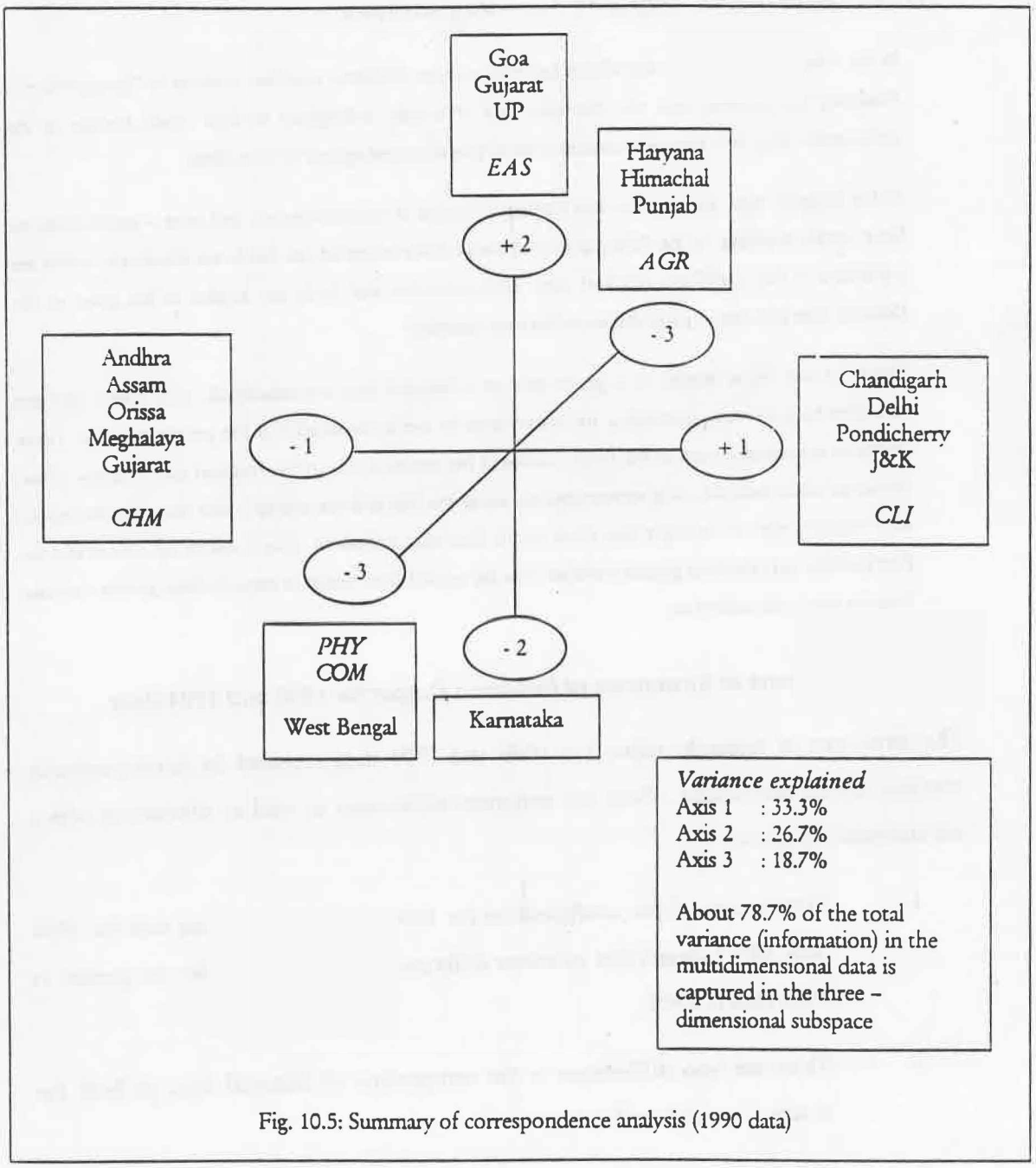


Fig. 10.5: Summary of correspondence analysis (1990 data)

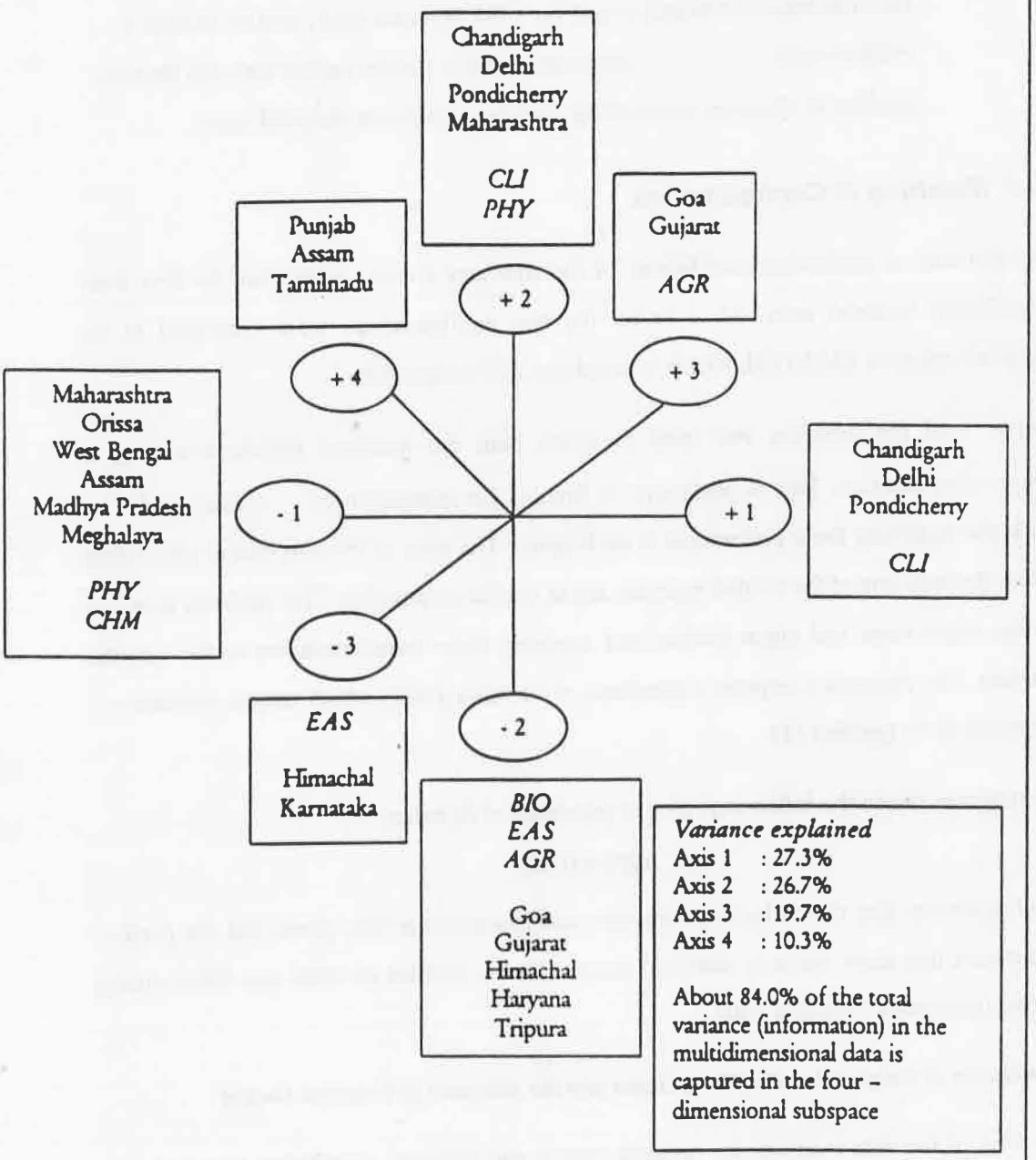


Fig. 10.6: Summary of correspondence analysis (1994 data)

(i.) Matching of the two configurations using Cliff's algorithm. This procedure provides a global index of concordance between the configurations.

(ii.) Introduction of the normalized profiles of research output for 1990 into the factorial map of research output for 1994, spanned by ϕ_1 and ϕ_2 axes as a mathematical model. This procedure reveals the deviations between the two profiles of different states along the most significant factorial axes.

10.3 Matching of Configurations

The matrices of projection coordinates of the row and column points on the first three (significant) factorial axes (24 × 4) for the two configurations were submitted to the computer program FMATCH, which is based on Cliff's algorithm.

Option 1 of the program was used to rotate both the matrices simultaneously to a compromise position. This is analogous to finding the orientation of .: – space and ⊘ – space and matching the *n* projections in each space. The axes of the two spaces are rotated so that the columns of the rotated matrices are as similar as possible. This problem is one of finding eigen roots and eigen vectors and applying these transformations to the original matrices. The program computes a goodness of fit index (*GFI*) which ranges between – 1 (worst fit) to +1 (perfect fit).

The program issued the following value of goodness of fit index:

$$GFI = 0.835$$

which indicates that the fit between the two configurations is very good, but not perfect. This means that there are only marginal changes in the profiles of states and fields during the two time spans 1990 and 1994.

Introduction of Cooperation Profiles of States into the Structure of Research Output

The rows of the data matrices for research output and intestate cooperation were merged, which resulted in a 48 × 11 matrix. Correspondence analysis was performed on this matrix. The rows for cooperation links were treated as supplementary variables.

Since all the 48 row points could not be displayed in one factorial map due to overlapping of points, the results of correspondence analysis are displayed in two superimposable factorial maps (Figures 10.7 and 10.8) – Andhra, Assam, Bihar, Chandigarh, Delhi, Goa, Gujarat, Haryana, Himachal, Jammu & Kashmir and Karnataka an Kerala, and the other for

Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Orissa, Pondicherry, Punjab, Rajasthan, Tamilnadu, UP and West Bengal.

In these maps, upper case letters representing the states pertain to the 1990 data and the lower case letters representing the states pertain to the 1994 data.

It can be easily seen from the maps that the distance between the corresponding points for research output and cooperation links is not the same for all states. For certain states, the distance is trivial, whereas for other states the distance is considerable. Lines have been drawn between the corresponding points of a state if the distance is considerable.

Considerable distances in the corresponding points of the following states are observed: Tripura, Orissa, Pondicherry, Punjab, Rajasthan, Assam and Goa.

These results indicate that there are hardly any changes in the research profiles of (scientifically) large states (i.e. the hard core of Indian science), whereas there are non-trivial changes in the research profiles of some of the smaller states.

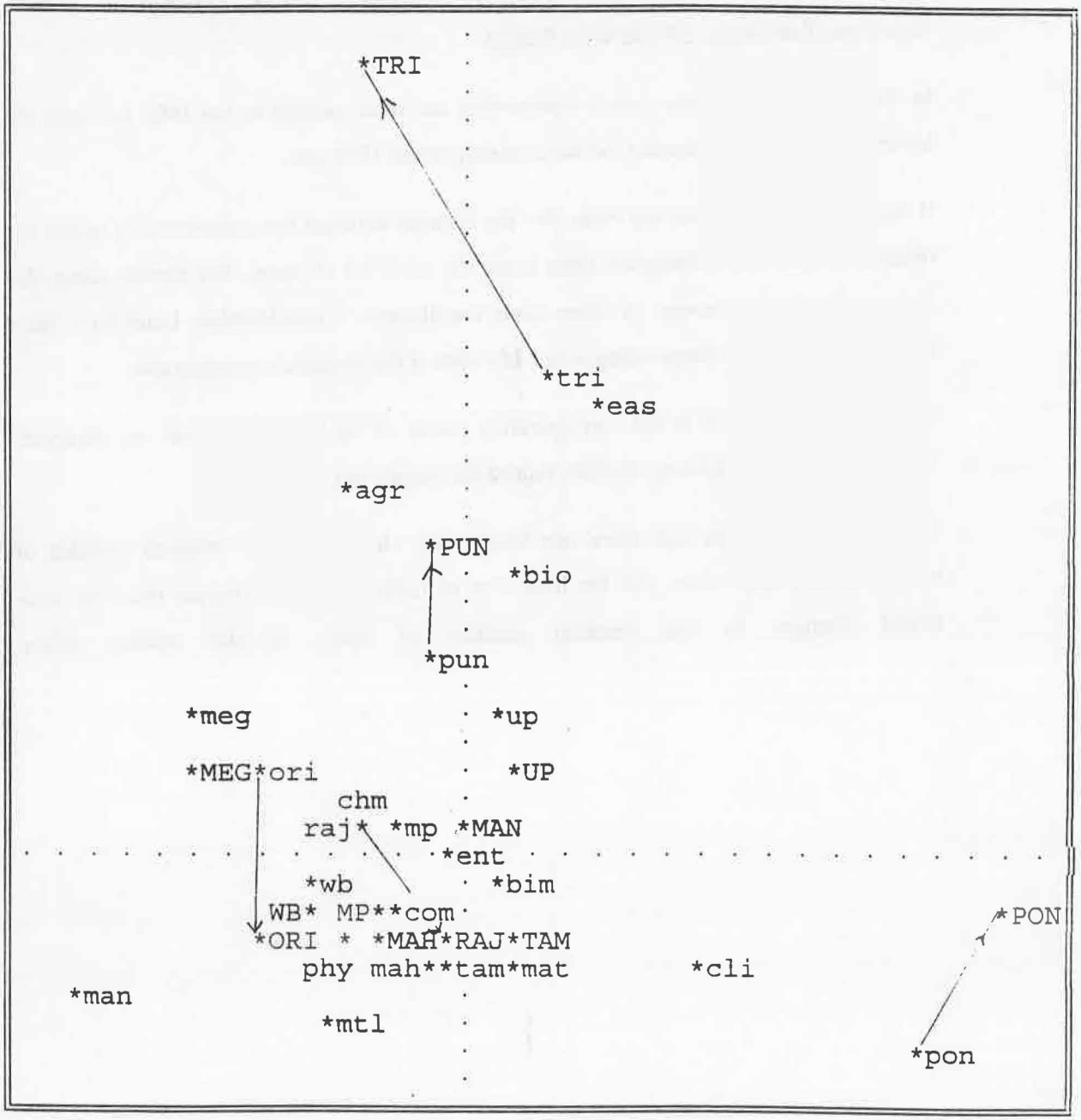


Fig. 10.7: Correspondence analysis map showing deviations between research output in 1990 and 1994 (Maharashtra to West Bengal)

State points for 1990 : lower case letters
State points for 1994 : upper case letters

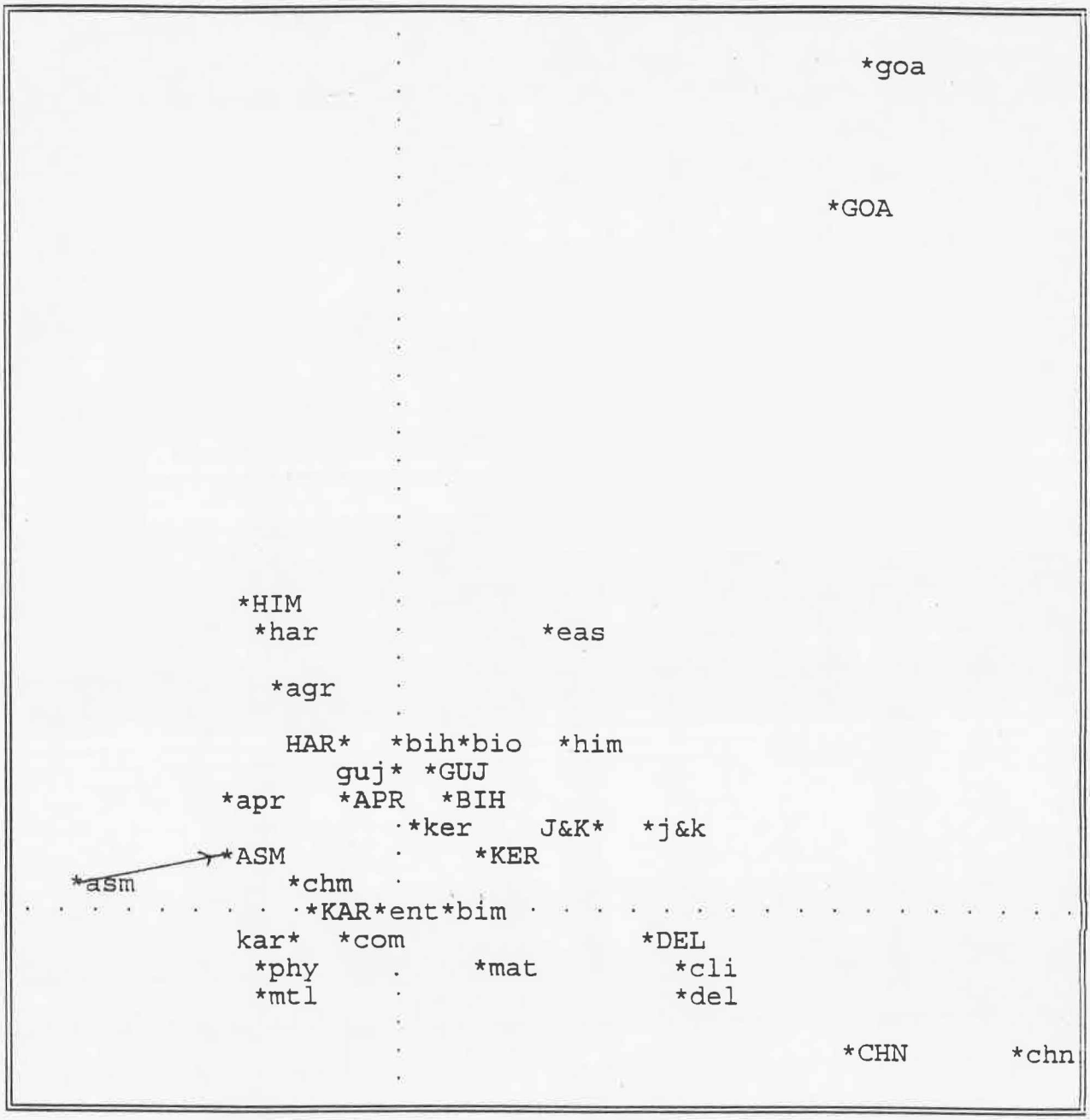


Fig. 10.8: Correspondence analysis map showing deviations between research output in 1990 and 1994 (Andhra to Kerala)

State points for 1990 : lower case letters
State points for 1994 : upper case letters

11 Interstate Co-operation

So far, we have examined the configurations of relationships of twenty eight states with eleven science fields on the basis of research output. But how are the states related among themselves? Which state cooperates with whom and to what extent?

The networks of cooperation links among the states can be depicted in the form of a (valued) adjacency matrix:

$$\mathbf{C} = |C_{ij}|$$

where C_{ij} indicates the number of cooperation links between state *i* and state *j*. Obviously, $C_{ii} = 0$. Since these links are bidirectional, the matrix is symmetric.

Tables 11.1 and 11.2 present the number of interstate links for 1990 and 1994.

During 1990, a total of 1302 cooperation links were observed, which for 756 cells, give a mean value of interstate links: 1.72. This is called the overall *density* of the network. About 67.5% of the cells (excluding the diagonal) are empty, indicating absence of any link. In 1994 the number of links increased to 2618; the density of network increased to 3.46. The overall characteristics of the networks for 1990 and 1994 are given in Table 11.3.

These results indicate that interstate cooperation has become not only more intensive, but also more expensive. In other words, the states which did not have any mutual connection in 1990, developed cooperation links in 1994.

Table 11.1 Inter-state collaboration Matrix -1990.

STATE	AND	APR	ARN	ASM	BIH	CHD	DEL	GOA	GUJ	HAR	HIM	J K	KAR	KER	MAP	MAH	MAN	MEG	MIZ	ORI	PON	PNJ	RAJ	SIK	TAM	TRI	UPR	WBN	TOT
AND																													0
APR				1	3	2	3	2	2	1		1	12	2	1	7		1		2	4		1		11		12	12	80
ARN				1																									1
ASM		1	1													1											1	4	8
BIH		3					8			1		1	4	1	1	2									2		12	6	41
CHD		2					18			2	4	6	1	1		9						7	4				1		55
DEL		3			8	18		2	4	11	1		7	2	5	20	1			4	3	8	7		10		45	11	170
GOA		2					2						1	1		5									3				14
GUJ		2					4				1		2	5	1	12				3					3		5	5	43
HAR		1			1	2	11				2	2		2		1						2	1				8	1	34
HIM						4	1		1	2												3					3		14
J&K		1			1	6				2												3	4				1		18
KAR		12			4	1	7	1	2					7	2	17					2		1		23		8	12	99
KER		2			1	1	2	1	5	2			7			4									7		6	2	40
MAH		1			1		5		1				2			8				3		1					12	1	35
MAN		7		1	2	9	20	5	12	1			17	4	8					6			7		29		12	13	153
MAP							1																1				1	5	8
MEG		1																									4	2	7
MIZ																											1		1
ORI		2					4		3						3	6											2	5	25
PNJ		4					3						2												3		2		14
PON						7	8			2	3	3			1												5		29
RAJ		1				4	7			1		4	1			7	1										9		35
SIK																													0
TAM		11			2		10	3	3				23	7		29					3						6	6	103
TRI																													0
UPR		12		1	12	1	45		5	8	3	1	8	6	12	12	1	4	1	2	2	5	9		6			17	173
WBN		12		4	6		11		5	1			12	2	1	13	5	2		5					6		17		102
																													0
TOT	0	80	1	8	41	55	170	14	43	34	14	18	99	40	35	153	8	7	1	25	14	29	35	0	103	0	173	102	1302

Table 11.2 Inter-state Collaboration Matrix - 1994

STATE	AND	APR	ARN	ASM	BIH	CHD	DEL	GOA	GUJ	HAR	HIM	J K	KAR	KER	MAP	MAH	MAN	MEG	MIZ	ORI	PON	PNJ	RAJ	SIK	TAM	TRI	UPR	WBN	TOT
AND																													0
APR							1	4	1	1				7	2	12		1			1				23		19	3	75
ARN		1														1												1	3
ASM					1		1		1			1		2		1	2	1			1		1		2		4		18
BIH											1		1	1	1	1					1	2					9	11	28
CHD		1		1	1		8			2	1	6		2		2				1	1	9	4		2		5		46
DEL		9		2	7				2	5	2	2	1	9	1	3				2	6	2	6		6		12	1	78
GOA		2		1	1	1	1		1			1	1	1		1				1	1		1		1			1	16
GUJ		3		4	1	1	7					1	7	4	3	24				7	3	1	4		4		9	12	95
HAR						1	7		1			2										2	1				6		20
HIM						1	1																						2
J&K					1		5	1		3				1							1		2		1		3		18
KAR		32		1	1	6	21			1		1		13	5	36		1		4	2		2		43		15	13	197
KER		1			1			1		1			2			1									7		1		15
MAH		13		3	8	11	28	6				4	4	1	19					2	4		6		19		16	21	165
MAN	1			2			2																					1	6
MAP		3			1		13		1	1						1		1							2		8	3	34
MEG																											3		3
MIZ																											1		1
ORI		2		4	1	1	12		1			2	2	5	1	8					3	1	1		5		7	7	63
PNJ					1	3	5			2	1	3															7		22
PON		4												1															5
RAJ				1	2	1	7			3		6		2	1	2				1	2				2		2	1	33
SIK																												1	1
TAM		7			7		17			1	1		5	12		4				1	11	1					7	1	75
TRI							1												1								1	2	5
UPR		3	1	4	4	2	45	1	4	2	3	1	3	14	9	12				5	5	1	7		13			4	143
WBN	2	7		5	9	5	17	1	1	1	1	5	1	7	3	9	7	2		6	4	1	3		14		13		124
TOT	3	88	1	28	47	33	199	14	13	23	10	35	27	82	45	118	9	6	1	30	46	20	38	0	144	0	148	83	1291

Table 11.3:
Overall characteristics of networks

	1990	*1994*
Total no. of links	1302	2618
Network density	1.72	3.46
No. of empty cells	510	384
% of empty cells	67.46	48.95

It is observed that some of the matrix cells are either empty or have very small values, whereas some other cells have large values, implying wide variations in mutual ties. The development of cooperation between any two states is influenced by geographical proximity, historical or political factors, culture and tradition. It is also influenced by the intervention of funding agencies – *e.g.* all India coordinated projects, etc. as well as by the dynamics of supply and demand.

Certain states have strong links with many other states; their network of cooperation is extensive. In other words, they occupy a central position in the network. On the other hand, there are certain states which have links with only a few states and thus occupy a peripheral position in the network. The centrality of a state refers to the attractiveness of its scientific community to attract cooperation from the scientific communities of other states. We have used the graph – theoretic measure of *Centrality* to quantify the position of different states in the network. If a state has connections with many other states in the network, its centrality would be high. If a state has connections with only a few states, its centrality would be low.

In this study, we have used the *Bonacich eigenvector centrality* measure to indicate the position of a state in the network. In this formulation, a link with a state occupying a central position counts more than a link with a state occupying a peripheral position. Thus, the centrality of a state is determined by the centralities of the states to which it is connected. *Bonacich eigenvector centrality* index ranges from 0 to 1. We have also computed the *Network Centralization Index*, which measures the centralization of the entire network. Larger this index, more likely that a single state is quite central and the remaining states are much less central. The less central states may be viewed as residing in the periphery of a

centralized system. The software *UCINET* IV was used to compute the eigenvector centralities of different states and the *Network Centralization Index*.

Table 11.4 presents the data on centralities of different states for 1990 and 1994. Three states viz. Andaman, Arunachal and Sikkim were excluded for the computation of the centrality index since these states were completely isolate in 1990.

The following trends are observed from Table 11.4:

1. The values of *Network Centralization Index* are not high indicating that the two networks are not very centralized. This means that no single state dominates the network.
2. The network centralization index has decreased, indicating that the network had become more decentralized. This means that some of the more 'central' state have become less central, and some of the peripheral states have become less central.
3. The value of eigenvector centrality index indicate that no state dominates the network, either in 1990 or 1994.
4. In general the centrality of larger states has decreased whereas that of smaller states increased in the interval between 1990 and 1994:
   (a) The centrality of the following states decreased: Bihar, Chandigarh, Delhi, Goa, Haryana, Himachal, Manipur, Meghalaya, Rajasthan, Uttar Pradesh, West Bengal.
   (b) The centrality of the following states increased: Andhra, Arunachal, Assam, Gujarat, Jammu and Kashmir, Kerala, Madhya Pradesh, Orissa, Tamilnadu.
   (c) There was no change in the centrality of the Maharashtra, Mizoram, Pondicherry and Punjab.

The entries in the (valued) adjacency matrix can be viewed in terms of both the overall levels of cooperation and patterns of cooperation. The overall level of cooperation is largely a function of the size of the state, while the pattern is not. The pattern of cooperation must be viewed without any confounding effects due to size. Since we are concerned primarily with the structure of the network, we have normalized the matrix for controlling the effect of size.

Table 11.4
Eigenvector centralities of different states

	1990	*1994*	*Change*
APR	0.219	0.290	↑
ARN	0.000	0.007	↑
ASM	0.022	0.057	↑
BIH	0.143	0.114	↓
CHD	0.145	0.097	↓
DEL	0.452	0.387	↓
GOA	0.047	0.041	↓
GUJ	0.132	0.162	↑
HAR	0.105	0.057	↓
HIM	0.029	0.018	↓
J_K	0.026	0.057	↑
KAR	0.291	0.361	↑
KER	0.116	0.172	↑
MAP	0.124	0.143	↑
MAH	0.399	0.399	≈
MAN	0.024	0.017	↓
MEG	0.026	0.014	↓
MIZ	0.004	0.002	≈
ORI	0.077	0.138	↑
PON	0.046	0.046	≈
PNJ	0.077	0.073	≈
RAJ	0.113	0.093	↓
TAM	0.314	0.339	↑
UPR	0.443	0.382	↓
WBN	0.283	0.262	↓
Network Centralization Index	56.55%	46.18%	

The normalized matrices represent essentially the structural features of the data devoid of distortions due to skewed marginal distributions. The entries in the matrix indicate the strength of cooperation links between pairs of states. The matrix however does not convey much information as it is not easy to discern the pattern of linkages from a large data

matrix. Since visual representation is useful in getting a sense of the data, we have transformed the normalized matrices into graphs.

The graphs were developed as follows: Euclidean distances between all the pairs of states was computed and the matrices of Euclidean distances, were subjected to Multidimensional Scaling (MDS). The multidimensional scaling algorithm locates states in a low - dimensional metricized space such that the states are located close together if they have a large number of ties with the same other partners. In other words, states which are 'structurally similar' are placed close together. The states which are structurally dissimilar are located far apart from each other. It should, however, be noted that the distance between any two points does not necessarily indicate the strength of relationships.

Krack Plot 3.0 was used to aesthetically improve the maps yielded by the MDS algorithm. The maps were re-oriented and rotated such that the resulting configuration approximated the location of the states as in a geographical map (with as few exceptions as possible). Then the points representing the states were adjusted for clarity, first manually and then through simulated annealing.

Figures 11.1 and 11.2 present the networks of cooperation links of 28 states for 1990 and 1994, wherein the arcs between the states indicate the strength of cooperation links above a certain threshold (> overall density of the normalized matrix).

The network presented in Figures 11.1 and 11.2 are quite revealing as they provide a synoptic view of state – by – state relationships. But the networks are quite complex and difficult to comprehend. The network for 1990 comprises 180 arcs and that for 1994 comprises 192 arcs. It is therefore essential to find a parsimonious representation of the total configuration by clustering the states

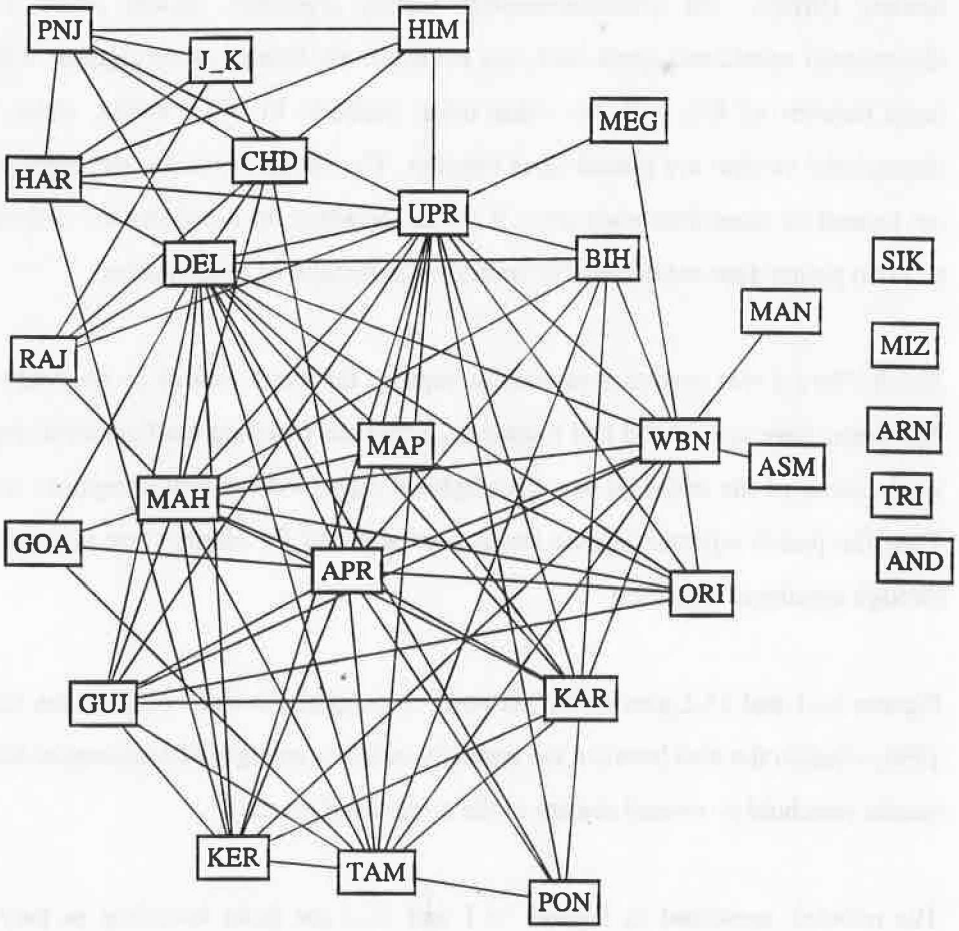


Fig 11.1: Network of Interstate Cooperation (1990)

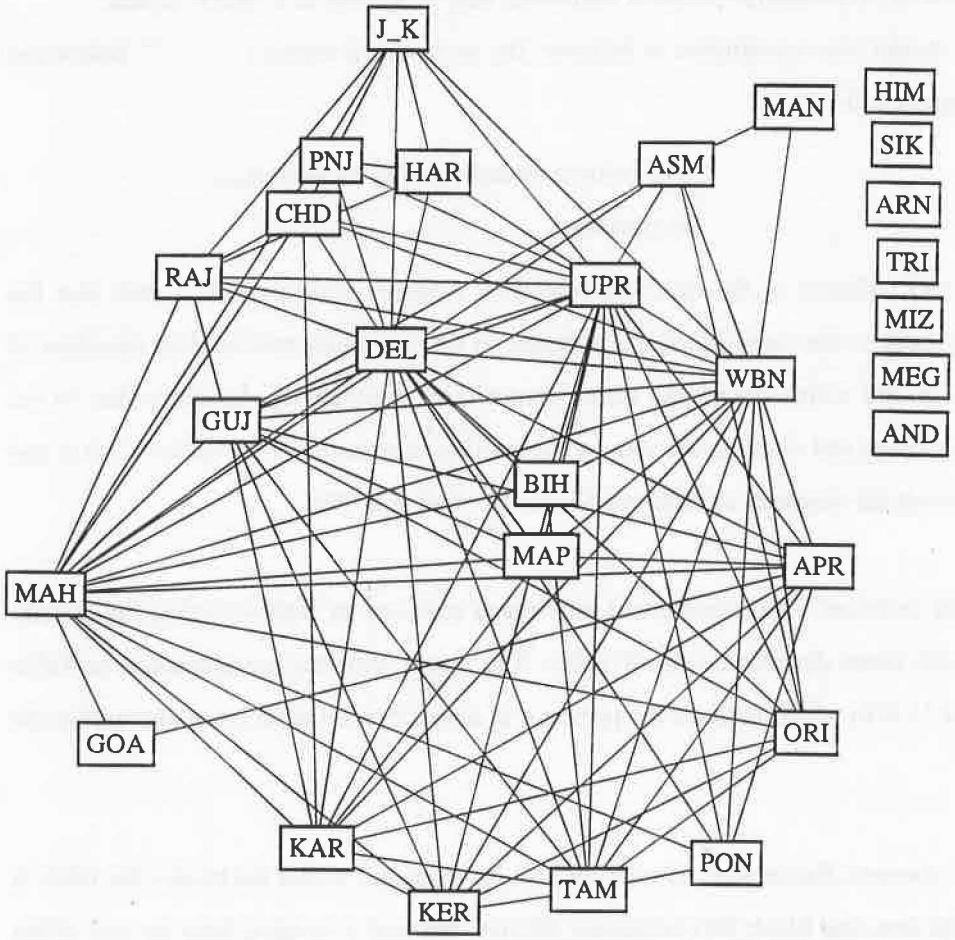


Fig 11.2: Network of Interstate Cooperation (1994)

into subgroups or 'blocks' and then depict the relationships among the subgroups. In social network analysis, subgroups are identified on the basis of certain graph – theoretic measures, *e.g.* structural equivalence or internal cohesion. Burt has pointed out that subgroups based on structural equivalence should be preferred to those based on cohesion. A number of algorithms are proposed in the literature for finding structurally equivalent subgroups or blocks. We have classified the states into blocks according to their structural equivalence using the Tabu search algorithm implemented in *UCINET*. The resulting configuration of relationships between the blocks may be termed as a 'block model'.

The block model was constructed as follows. The normalized matrix of was dichotomized by recoding the cell values:

1 if value ≥ overall density of the matrix

0 otherwise

The rows and columns of the resulting adjacency matrices were permuted such that the states belonging to the same block are adjacent in the permuted matrix. The densities of links between and within the blocks were computed by summing up the cell values in the permuted matrices and dividing the sum by the number of possible cells. Tables 11.5(a) and 11.6 (a) present the densities of different blocks for 1990 and 1994.

The 'density matrices' was transformed into image matrices by dichotomizing the density matrices with mean density as cut-off value. The image matrices are presented in Table 11.5(b) and 11.6(b) which indicate the presence or absence of links between and within the blocks.

Figure 11.3 presents the network of relationships between and within the blocks for 1990. It can be easily seen that block B8 (Andaman, Sikkim, Tripura) is isolated from the rest of the blocks. Block B2 (Goa, Arunachal Pradesh, Manipur, Orissa, Pondicherry, Assam, Mizoram) is a satellite of block B6 (Andhra, West Bengal). There are no internal connection within block B2. Similarly block B3 (Kerala, Gujarat) is a satellite for block B4 (Karnataka, Maharashtra and Tamilnadu) and block B5 (Himachal and Jammu & Kashmir) is a satellite of block B7 (Maharashtra, Haryana, Bihar, Punjab and Rajasthan). Block B4 occupies a central position in the blockmodel it is connected to four other blocks, whereas blocks B1 (Delhi and UP), B6 and B7 are each connected to three other blocks.

Figure 11.4 presents the network of relationships between and within the blocks for 1994. It can be easily seen that blocks B1 (Andaman, Arunachal, Meghalaya, Mizoram, Tripura,

Sikkim, Goa, Himachal, Manipur, Orissa and Bihar) and B3 (Rajasthan, Pondicherry, Punjab, Chandigarh, Jammu & Kashmir, Assam and Haryana) are isolated from the rest of the blocks. Block B7 (Maharashtra) occupies a central position in the blockmodel.

Table 11.5(a)
Density of Links between block for 1990

	B1	B2	B3	B4	B5	B6	B7	B8
B1	6.91	1.61	1.31	4.84	0.38	3.30	7.99	0
B2	1.61	0.15	0.31	1.61	0.00	2.00	0.31	0
B3	1.31	0.31	0.77	2.69	0.08	0.84	0.38	0
B4	4.84	1.61	2.69	10.60	0.00	4.69	2.84	0
B5	0.38	0.00	0.08	0.00	0.00	0.08	1.92	0
B6	3.30	2.00	0.84	4.69	0.08	1.84	1.23	0
B7	7.99	0.31	0.38	2.84	1.92	1.23	2.92	0
B8	0	0	0	0	0	0	0	0

Legend:

β_1 : DELHI, UP
β_2 : GOA, ARUNACHAL PRADESH, MANIPUR, ORISSA, PONDICHERRY, ASSAM, MIZORAM
β_3 : KERALA, GUJARAT
β_4 : KARNATAKA, MAHARASHTRA, TAMILNADU
β_5 : HIMACHAL, JAMMU & KASHMIR
β_6 : ANDHRA PRADESH, WEST BENGAL
β_7 : MAHARASHTRA, HARYANA, BIHAR, PUNJAB, RAJASTHAN
β_8 : ANDMAN, SIKKIM, TRIPURA

Table 11.5(b)
Image matrix for 1990 (Using cutoffs = mean density)

	B1	B2	B3	B4	B5	B6	B7	B8
B1	1	0	0	1	0	1	1	0
B2	0	0	0	0	0	1	0	0
B3	0	0	0	1	0	0	0	0
B4	1	0	1	1	0	1	1	0
B5	0	0	0	0	0	0	1	0
B6	1	1	0	1	0	1	0	0
B7	1	0	0	1	1	0	1	0
B8	0	0	0	0	0	0	0	0

Table 11.6(a)
Density of Links between block for 1994

	B1	B2	B3	B4	B5	B6	B7	B8
B1	0.00	0.01	0.01	0.01	0.04	0.02	0.03	0.08
B2	0.01	0.04	0.06	0.12	0.44	0.15	0.36	0.63
B3	0.01	0.06	0.11	0.05	0.29	0.07	0.18	0.14
B4	0.01	0.12	0.05	0.10	0.49	0.29	0.70	0.33
B5	0.04	0.44	0.29	0.49	2.18	0.79	1.13	0.67
B6	0.02	0.15	0.07	0.29	0.79	1.40	1.12	0.50
B7	0.03	0.36	0.18	0.70	1.13	1.12	0.00	1.15
B8	0.08	0.63	0.14	0.33	0.67	0.50	1.15	0.00

Legend:

β_1 : ANDAMAN, ARUNACHAL, MEGHALAYA, MIZORAM, TRIPURA, SIKKIM, GOA, HIMACHAL, MANIPUR
β_2 : ORISSA, BIHAR
β_3 : RAJASTHAN, PONDICHERRY, PUNJAB, CHANDIGARH, JAMMU & KASHMIR, ASSAM, HARYANA
β_4 : GUJARAT, KERALA, MADHYA PRADESH
β_5 : UTTAR PRADESH, DELHI
β_6 : ANDHRA PRADESH, KARNATAKA, TAMILNADU
β_7 : MAHARASHTRA
β_8 : WEST BENGAL

Table 11.6(b)
Image matrix for 1994 (Using cutoffs = mean density)

	B1	B2	B3	B4	B5	B6	B7	B8
B1	0	0	0	0	0	0	0	0
B2	0	0	0	0	1	0	1	1
B3	0	0	0	0	0	0	0	0
B4	0	0	0	0	1	0	1	0
B5	0	1	0	1	1	1	1	1
B6	0	0	0	0	1	1	1	1
B7	0	1	0	1	1	1	0	1
B8	0	1	0	0	1	1	1	0

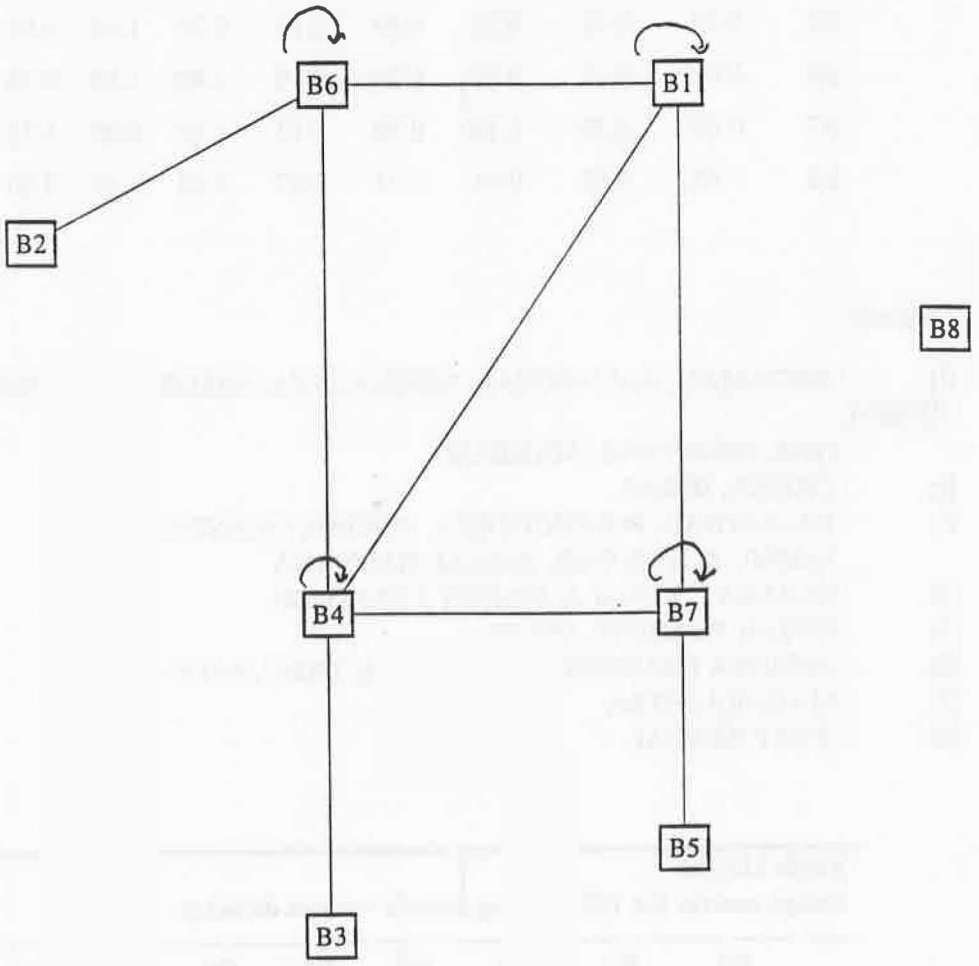


Fig 11.3: Blockmodel of Interstate Cooperation (1990)

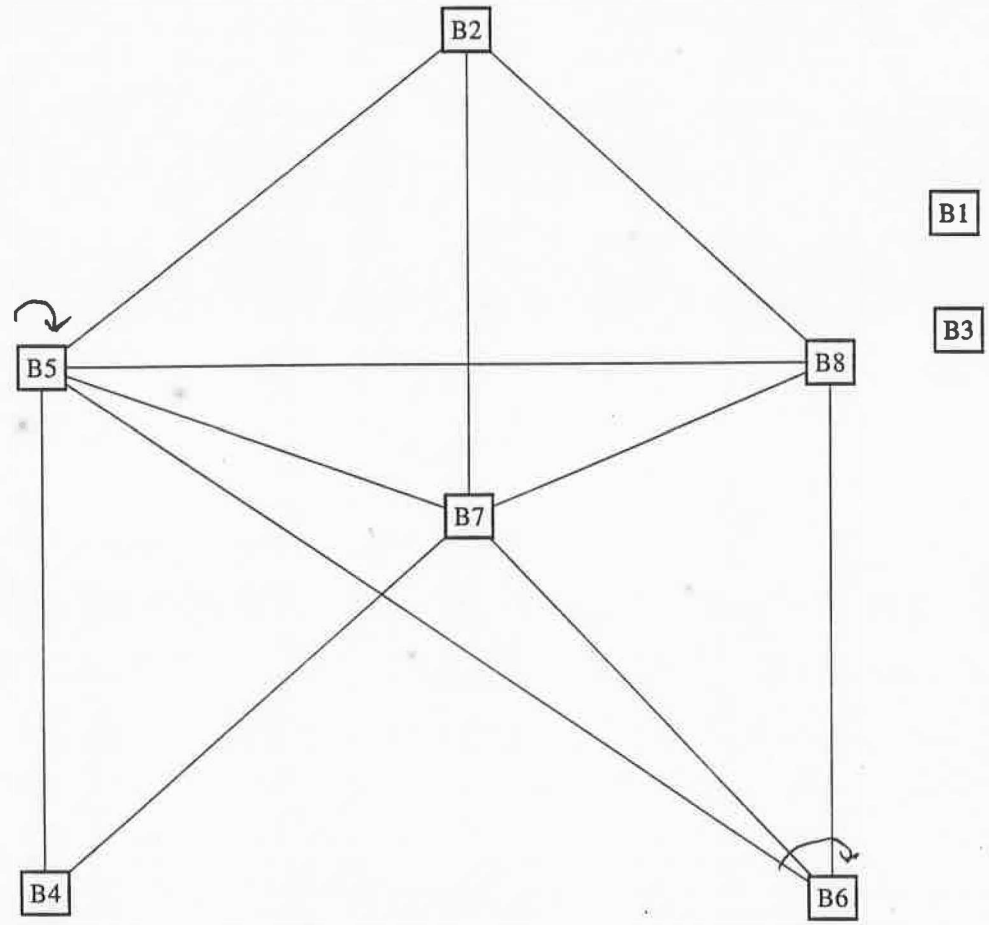


Fig 11.4: Blockmodel of Interstate Cooperation (1994)

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Appendices

Appendix 1

Major Scientific Agencies and Other Departments

1	DAE	Department of Atomic Energy
2	CSIR	Council of Scientific and Industrial Research
3	DRDO	Defence Research Development Organisation
4	DOE	Department of Electronics
5	MOEn	Ministry of Environment and Forests
6	ICAR	Indian Council of Agricultural Research
7	ICMR	Ian Council of Medical Research
8	DBT	Department of Biology-Technology
9	DSIR	Department of Scientific and Industrial Research
10	DOS	Department of Space
11	DA&C	Department of Agriculture and Cooperation
12	DAHD	Department of Animal Husbandary and Dairying
13	DCP	Department of Chemicals and Petrochemicals
14	DOF	Department of Fertilizers
15	DCA	Department of Civil Aviation
16	MCS	Department of Civil Supplies
17	MOC	Ministry of Coal
18	MOCo	Ministry of Commerce
19	DOT	Department of Telecommunications
20	DODe	Depatment of Defence
21	DDPS	Department of Defence Production and Supplies
22	MOFo	Ministry of Food
23	MFPI	Ministry of Food Processing Industries
24	MHFW	Ministry of Health and Family Welfare
25	MHA	Ministry of Home Affairs
26	DOCu	Department of Culture
27	DHI	Department of Heavy Industry
28	DID	Department of Industrial Development
29	DSSI	Department of Small Scale Industries, Agro and Rural Industries
30	MI&B	Ministry of Information and Broadcasting
31	MOL	Ministry of Labour
32	MOM	Ministry of Mines
33	MPNG	Ministry of Petroleum and Natural Gas
34	DOSt	Department of Statistics
35	MOP	Ministry of Power
36	MOR	Ministry of Railways
37	MRD	Ministry of Rural Development
38	MOSI	Ministry of Steel
39	MSTt	Ministry of Surface Transport
40	MUD	Ministry of Urban Development
41	MOW	Ministry of Welfare
42	MOTx	Ministry of Textiles
43	MWR	Ministry of Water Resources
44	MHRD	Ministry of Human Resources Development
45	MNCER	Ministry of Non Conventional Energy Resources
46	DOM	Department of Meteorology

Appendix 2

ISO standard country codes

CODE	COUNTRY
	Armenia
	Byelarus
AFG	Afghanistan
AFI	Afars & Iss
AGO	Angola
ALB	Albania
ANT	Neth Antillas
ARE	United Arab Emir
ARG	Argentina
ASM	American Samoa
ATA	Antarctica
AUS	Australia
AUT	Austria
BDI	Burundi
BEL	Belgium
BEN	Benin
BEU	Belau
BGD	Bangladesh
BGR	Bulgaria
BHR	Bahrain
BHS	Bahamas
BHU	Bhutan
BIG	Bissau Guinea
BLZ	Belize
BMU	Bermuda
BOL	Bolivia
BPW	Bophuthatswana
BRA	Brazil
BRB	Barbados
BRN	Brunei
BUR	Burma
BWA	Botswana
CAF	Central Africa
CAN	Canada
CHE	Switzerland
CHL	Chile
CIK	Ciskei
CIV	Ivory Coast
CMR	Cameroon
COG	Congo PR
COK	Cook Island
COL	Colombia
CRI	Costa Rice
CSK	Czechoslovakia
CUB	Cuba
CYP	Cyprus
DDR	German DR
DEU	Germany FR
DNA	Dominican Rep
DNK	Denmark
DZA	Algeria
ECU	Ecuador
EGY	Egypt
EQG	Equat Guinea
ESP	Spain
ETH	Ethiopia
FIN	Finland
FJI	Fiji
FRA	France
GAB	Gabon
GHA	Ghana
GIB	Gibralter
GIN	Guinea
GLP	Guadeloupe
GRC	Greece
GRL	Greenland
GTM	Guatemala
GUF	French Guyana
GUY	Guyana
HKG	Hong Kong
HND	Honduras
HTI	Haiti
HUN	Hungary
HVO	Upper Volta
IDN	Indonesia
IND	India
IRL	Ireland
IRN	Iran
IRQ	Iraq
ISL	Iceland
ISR	Israel
ITA	Italy
JAM	Jamaica
JOR	Jordan
JPN	Japan
KEN	Kenya
KIR	Kiribati
KOR	South Korea
KWT	Kuwait
LAO	Laos
LBN	Lebanon
LBR	Liberia
LBY	Libya
LIE	Liechtenstein
LKA	Sri Lanka
LSO	Lesotho
LUX	Luxembourg
MAR	Morocco
MAU	Mauritania
MCO	Monaco
MDG	Malagasy Rep
MEX	Mexico
MIC	Micornesia
MIL	Marchall Islands
MLI	Mali
MLT	Malta
MNG	Mongol PR
MOZ	Mozambique
MTQ	Martinique
MUS	Mauritius
MWI	Malawi
MYS	Malaysia
NAM	Namibia
NGA	Nigeria
NCL	New Caledonia
NGR	Niger
NIC	Nicaragua
NIU	Niue
NLD	Netherlands
NOR	Norway
NPL	Nepal
NZL	New Zealand
OMN	Oman
PAK	Pakistan
PAN	Panama
PER	Peru
PHL	Philippines
PNG	Papua New Guinea
POL	Poland
PRC	PR China
PRK	North Korea
PRT	Portugal
PRY	Paraguay
PYF	French Polynesia
QAT	Qatar
REU	Reunion
ROM	Romania
RWA	Rwanda
SAU	Saudi Arabia
SDN	Sudan
SGA	Senegambia
SGP	Singapore
SIK	Sikkim
SLB	Soloman Isl
SLE	Sierra Leone
SLV	EL Salvador
SMR	San Marino
SOM	Somalia
SSA	Spanish Sahara
SUN	USSR
SUR	Surinam
SWE	Sweden
SWZ	Swaziland
SYC	Seychelles
SYR	Syria
TCD	Chad
TGO	Togo
THA	Thailand
TON	Tonga
TRK	Transkei
TTO	Trinidad & Tobago
TUN	Tunisia
TUR	Turkey
TWN	Taiwan
TZA	Tanzania
UGA	Uganda
UKD	UK
URY	Uruguay
USA	USA
VAT	Vatican
VEN	Venezuela
VND	Venda
VNM	Vietnam
VUT	Vanuatu
WIA	W Indian Assoc
WSM	Western Samoa
YEM	Yemen Arab Rep
YMD	Yemen PDR
YUG	Yugoslavia
ZAF	South African R
ZAR	Zaire
ZMB	Zambia
ZWE	Zimbabwe

Appendix 3

Subject Classification system

Science

1. Mathematics
2. Physics
3. Chemistry
4. Biology
5. Earth & Atmospheric Sciences
6. Food & Agriculture Research
7. Clinical Medicine
8. Biomedical Research
9. Engineering and Technology
10. Computer Science
11. Materials Science
12. Multi-Disciplinary

Physics

General Physics
Solid State Physics
Applied Physics
Nuclear & Particle Physics
Chemical Physics
Astronomy & Astrophysics
Optics
Crystallography
Spectroscopy
Acoustics
Fluids & Plasmas
Mathematical Physics
Microscopy

Chemistry

Organic Chemistry
Inorganic & Nuclear Chemistry
General Chemistry
Physical Chemistry
Polymers
Analytical Chemistry
Electro Chemistry
Applied Chemistry

Agriculture

Agriculture & Food Sciences
Food Science
Agricultural Soil Sciences
Dairy & Animal Sciences
Horticulture
Forestry
Agricultural Economics & Policy

Earth & Space Sciences

Environmental Sciences
Earth & Planetary Sciences
Geology
Remote Sensing
Meteorology & Atmospheric Sciences
Oceanography & Limnology

Biology

Botany-Plant Science
General Biology
Marine Biology + Hydrobiology
Entomology
Ecology
Misc. Biology
General Zoology
Misc. Zoology

Mathematics

1.General Mathematics
2. Applied Mathematics
3. Inter-disciplinary Mathematics
4. Probability and Statistics
5. Operational Research & Management Science

Appendix 3 (Continued)

Biomedical Research

Biochem. & Mole. Bio.
Microbiology
General Biomed. Res.
Genetics & Heredity
Biomed. Engn
Nutrition & Dieteics
Virology
Parasitology
Cell Biology., Cyto. & Histo
Misc. Biomedcial Res.
Embryology
Biophysics
Anatomy & Morphology
Physiology

Material Science

General Material Science
Ceramic Materials
Biomaterials
Characterization of Materials
Textiles, Fibres, Leather
Coatings & Films
Paper & Pulp Wood
Composites

Engineering & Technology

Elec. Engn. & Electronics
Mechanical Engn.
Metals & Metallurgy
Chemical Engn.
Misc. Engn. & Tech
Civil Engineering
Aerospacetech
Nuclear Tech.
General Engn.
Telecom. Engn.

Computers & Communication Science

Miscellaneous
Artificial Intelligence
Information System
Interdisciplinary Applications
Cybernetics
Theory & Methodology
Hardware & Architecture
Robotics & Automatic Control
Software + Graphics

Clinical Medicine

Gastroenterology
Hygiene & Public Health
Neurol & Neurosur
Cancer
Immunology
Radio. & Nuc. Clinical Medicine.
Gen. & Internal Clinical Medicine.
Surgery
Ophthalmology
Endocrinology
Pathology
Urology
Cardiovas. system
Pediatrics
Andrology
Pharmacy
Dentistry
Fertility
Anesthesiology
Der. & Veneral Diseases
Hematology
Respiratory System
Pharmacology
Nephrology
Allergy
Otorhinolaryngology
Misc. Clinical Medicine
Geriatrics
Psy. & Behavioural Sci.
Addictive Diseases
Trop. Medicine
Orthopaedics
Vet. Clinical Medicine.
Arthritis & Rheumatism
Obst. & Gyn

Appendix 4

States and Union territories of India

ANDAMAN & NICOBAR	AND
ANDHRA PRADESH	APR
ARUNACHAL PRADESH	ARN
ASSAM	ASM
BIHAR	BIH
CHANDIGARH	CHD
DELHI	DEL
GOA	GOA
GUJARAT	GUJ
HARYANA	HAR
HIMACHAL PRADESH	HIM
JAMMU & KASHMIR	J&K
KARNATAKA	KAR
KERALA	KER
MADHYA PRADESH	MAP
MAHARASHTRA	MHA
MANIPUR	MAN
MEGHALAYA	MEG
MIZORAM	MIZ
ORISSA	ORI
PONDICHERRY	PON
PUNJAB	PNJ
RAJASTHAN	RAJ
SIKKIM	SIK
TAMIL NADU	TAM
TRIPURA	TRI
UTTAR PRADESH	UPR
WEST BENGAL	WBN