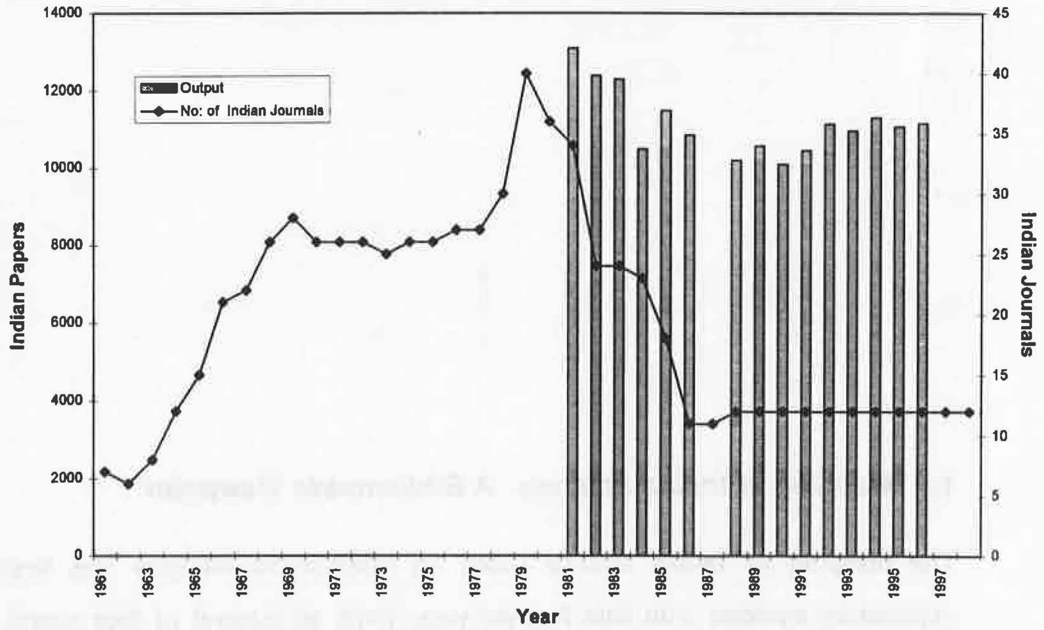
1 Executive Summary

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.

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[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

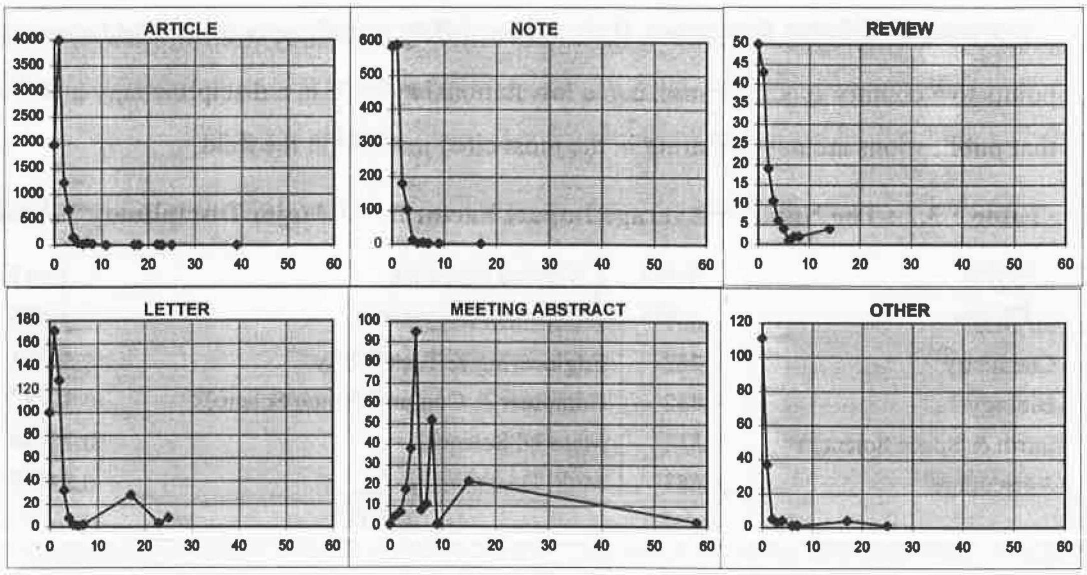
Table1.2.1 Percentage of Papers in Categories by Type

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

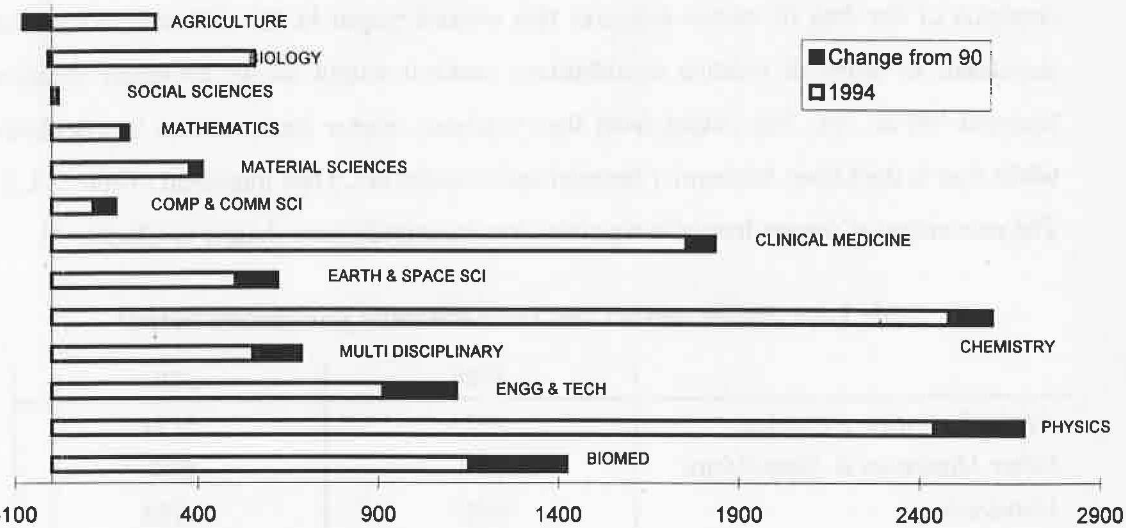
Table 1.3.2 indicates considerable variation in the national averages of the IF of different disciplines. This could be due to intrinsic reasons such as variations in the citation practices of different disciplines. If the values differs significantly from world averages it points to a country specific 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

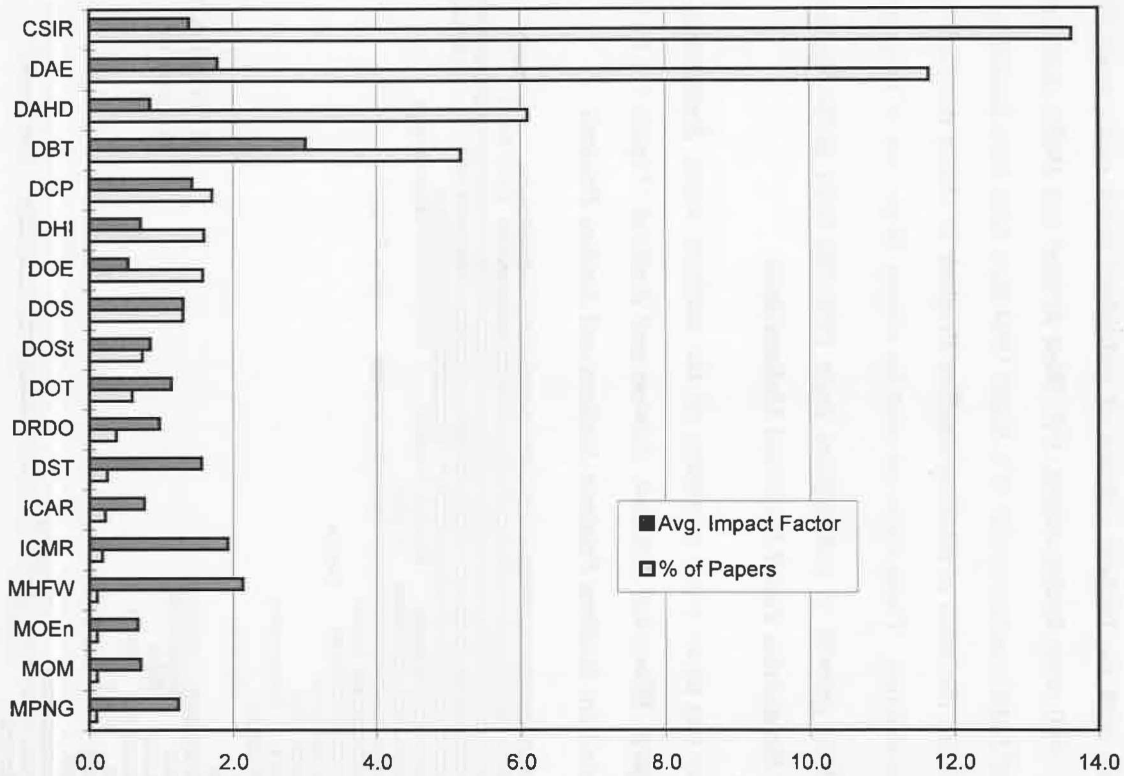
	1990	*1994*
Major Scientific Agencies,	*3831*	*5173*
Other Ministries & State Sector	*252*	*837*
Universities,	*4007*	*4188*
Others Academic Sector	*1979*	*2408*
Industrial Sector	*277*	*369*
Health Sector	*596*	*602*
Total	*11124*	*13267*

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***.

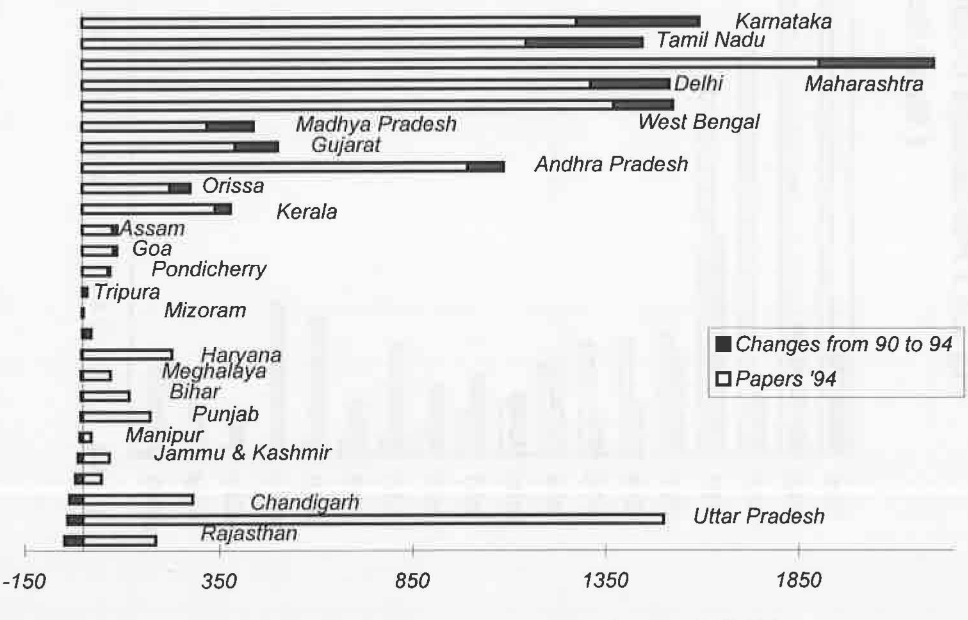


Fig 1.5.1 Output of Scientific Publications from Indian States SCI 1994

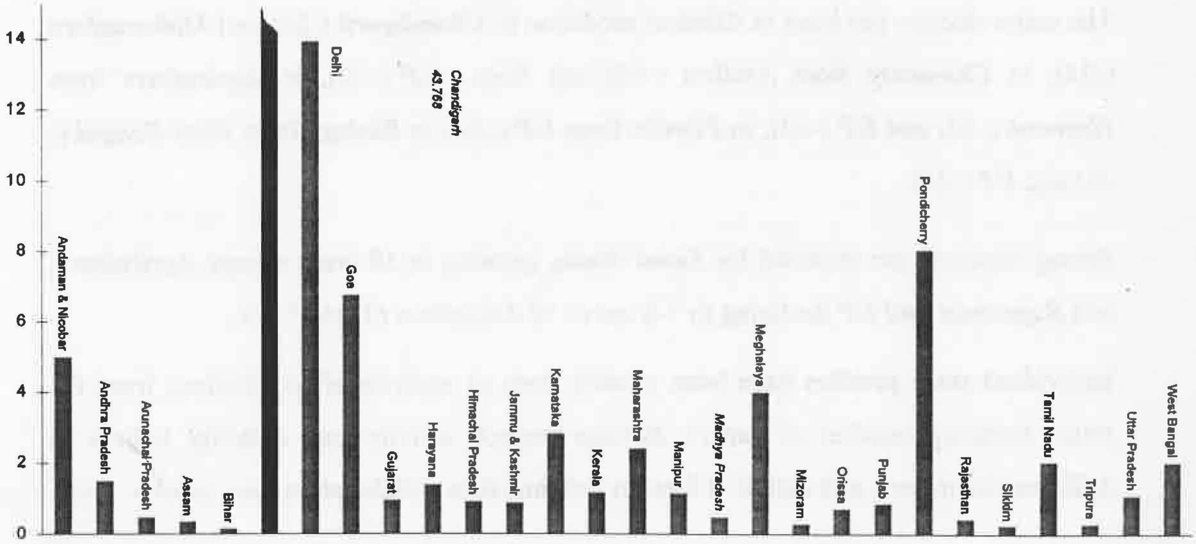
1.5.1 Scientific output of states per unit Population

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 unexpectedly, 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		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		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

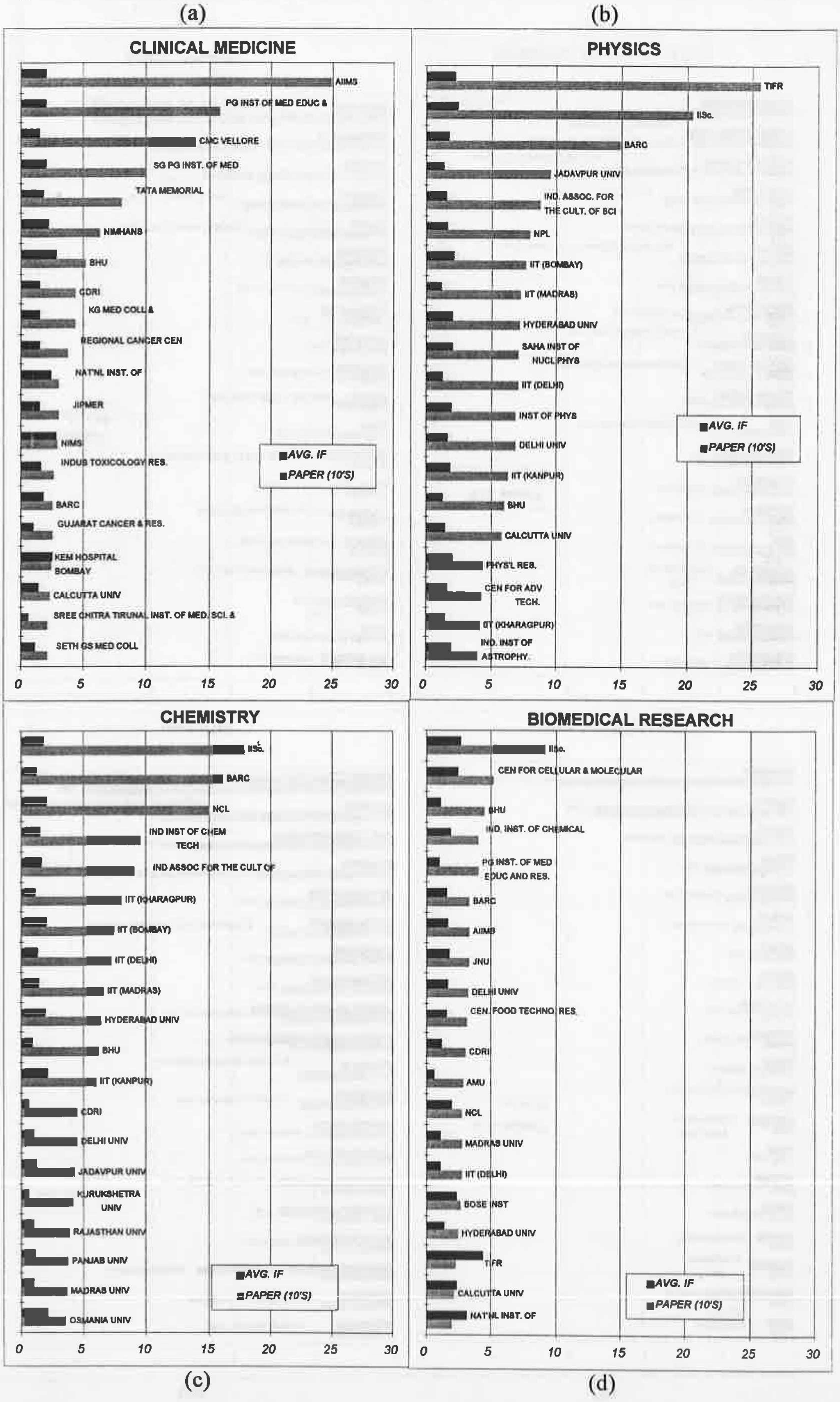
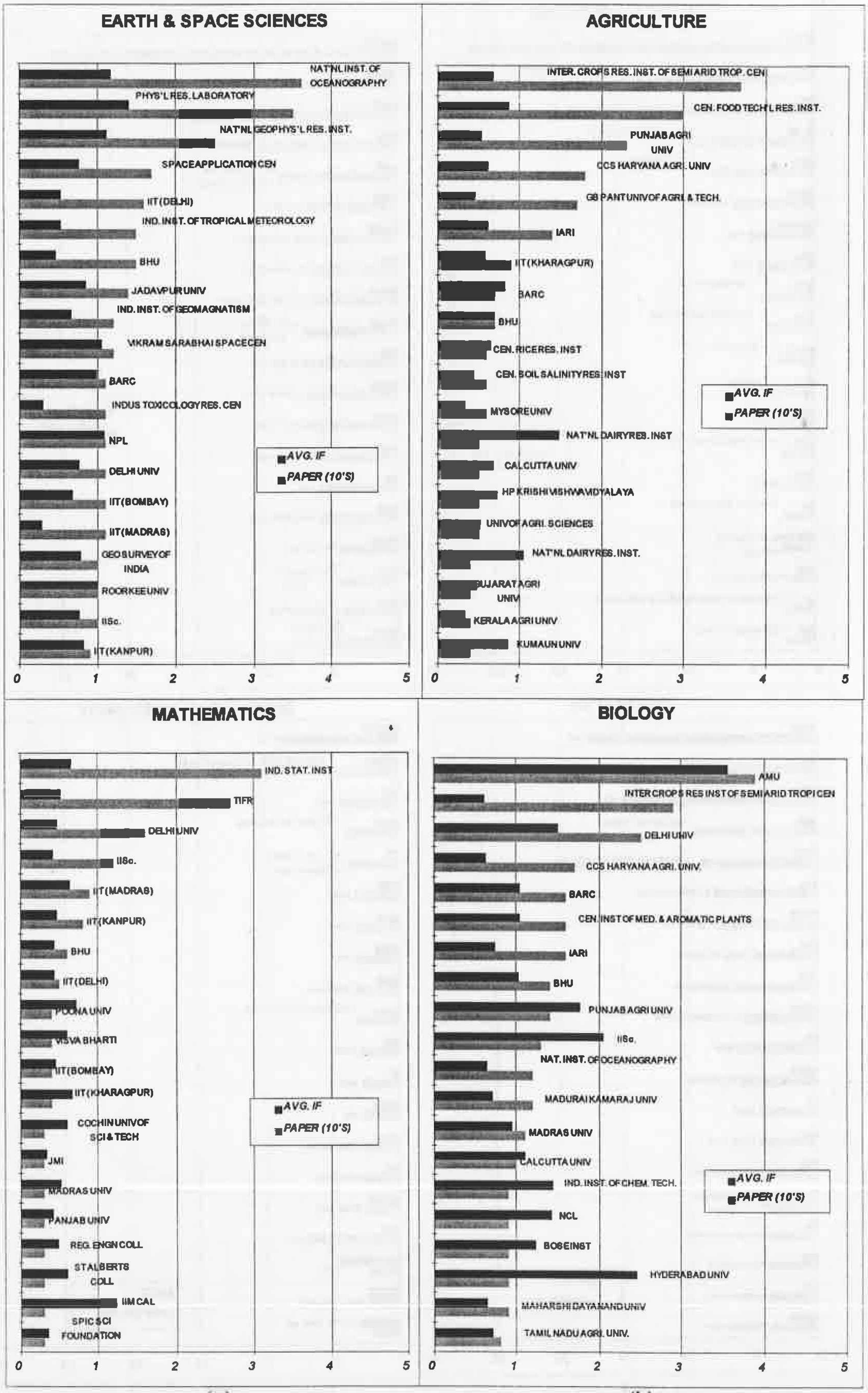


Fig 1.6.1 SCIENTIFIC PUBLICATION OUTPUT OF INDIAN INSTITUTIONS - 1994

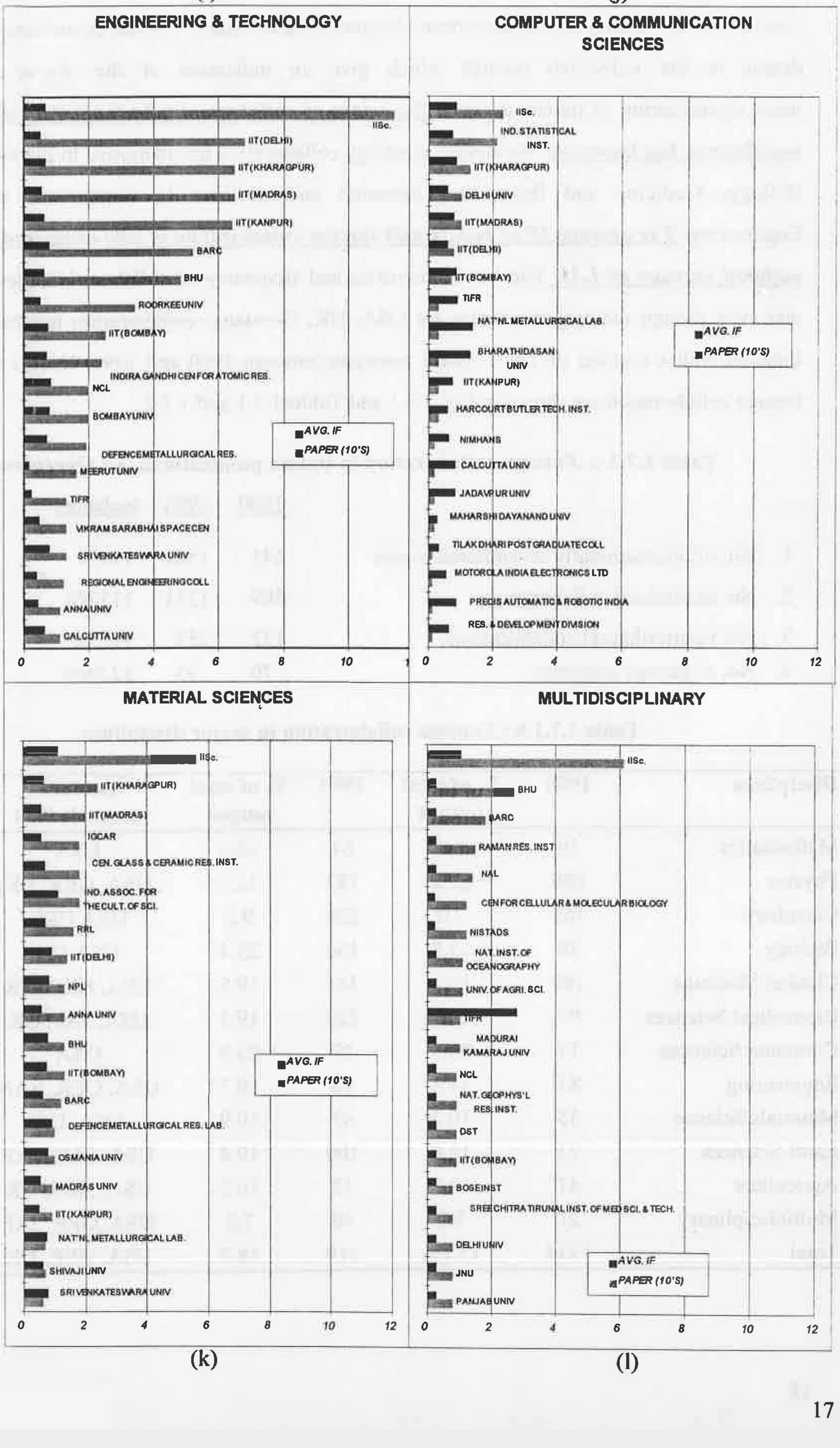
(e) (f)



(g) (h)

Fig 1.6.1 SCIENTIFIC PUBLICATION OUTPUT OF INDIAN INSTITUTIONS - 1994

(i) (j)



(k) (l)

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

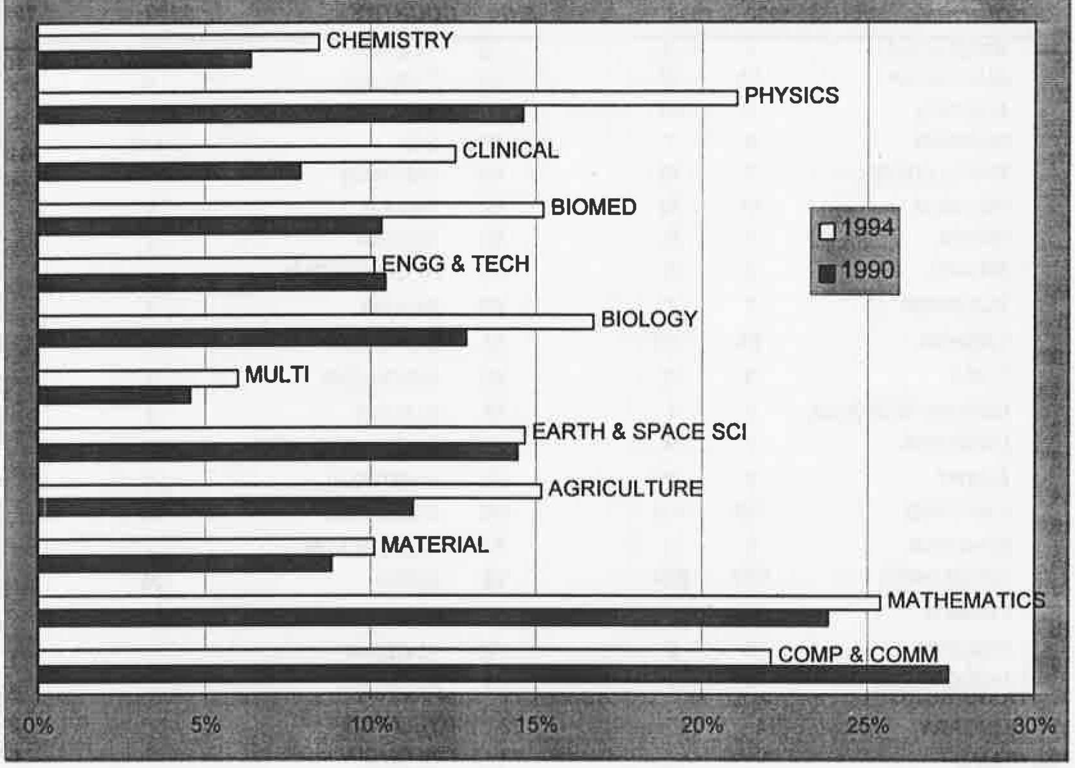


Fig 1.7.1b -Change in the No. of Bi-lateral and Multi-lateral Collaborations (1990 : 1994)

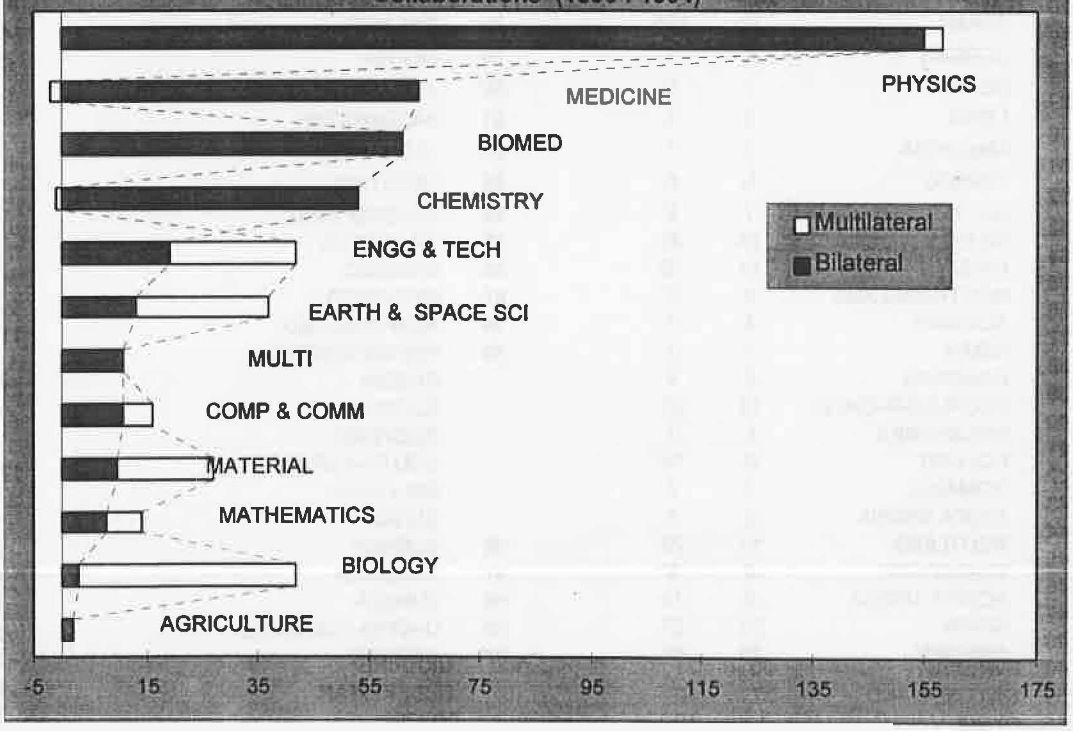


Table 1.7.2 Frequency of India's Foreign Collaboration in 1990 & 1994

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*

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.

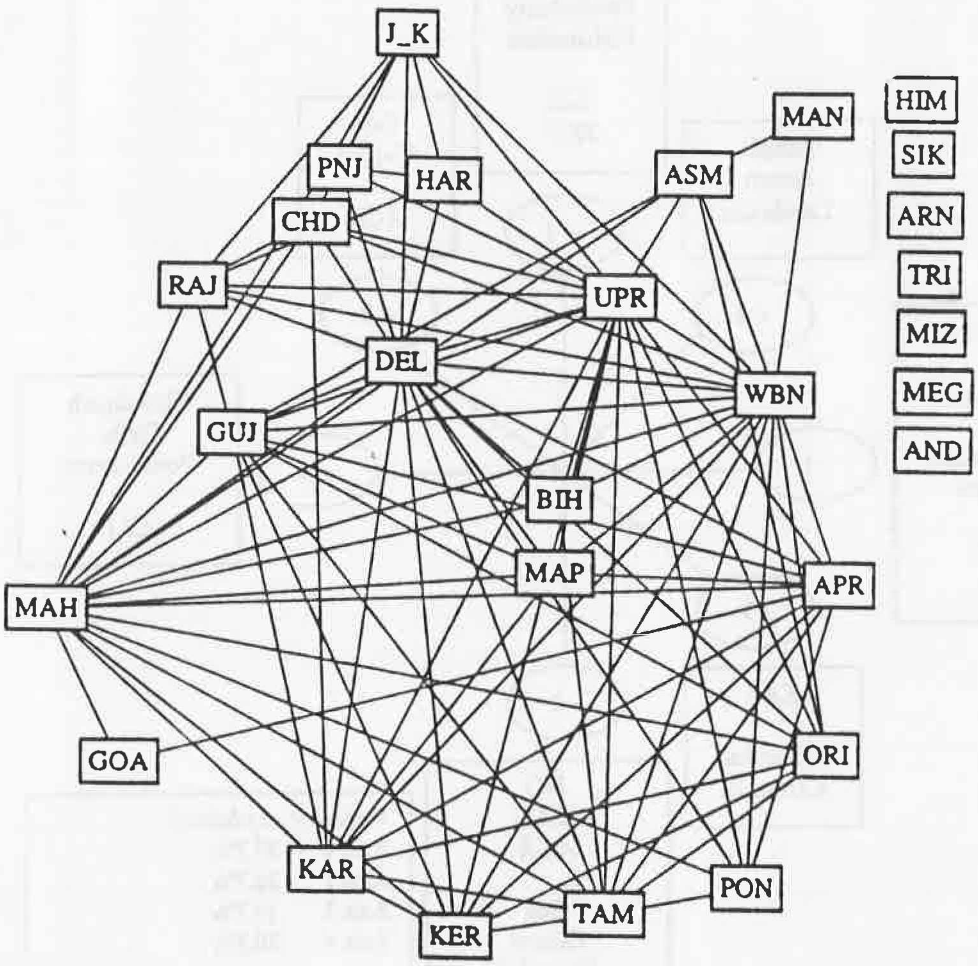


Fig 1.8 Network of Scientific Co-operation of Indian States (1994)

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.

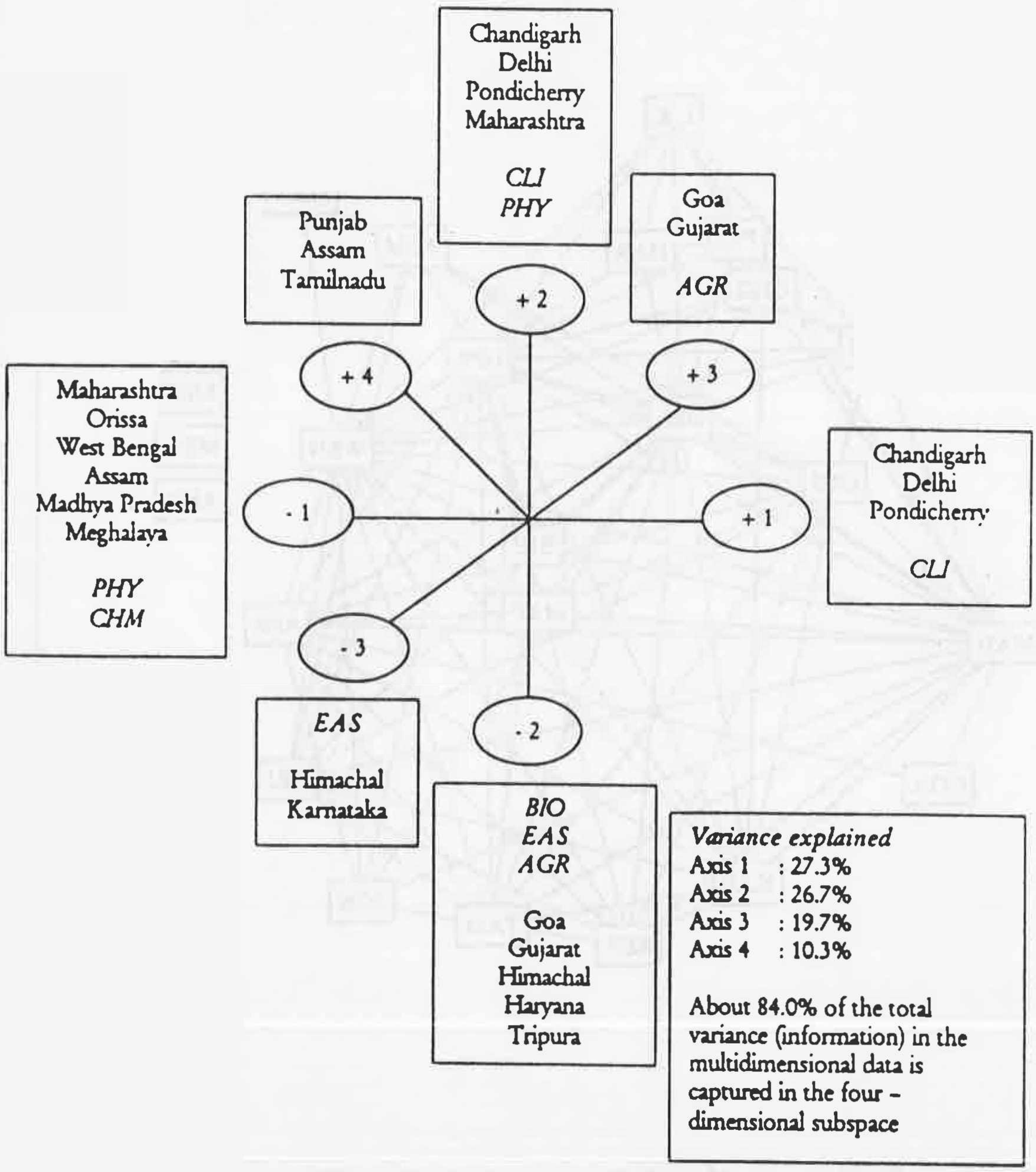


Fig 1.9 Summary of Correspondence Analysis (1994 data)

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.