Preface

Regional distribution of science and cooperation among different regions are two important issues of national science policy. In this study we have analyzed the patterns of research output and cooperation links among 28 states of the Indian Union. In this context, the following issues are of crucial importance. (i) What is the volume and pattern of research output of different states of the Indian Union? (ii) what is the volume and pattern of scientific cooperation among the states?

This study, sponsored by the National Information System for Science and Technology (NISSAT), Department of Scientific and Industrial Research (research grant # NI/SS/068/94) addresses these issues.

Interstate cooperation is visualized along two dimensions: (i) cooperation activity of a state in different research fields; (ii) cooperation links of a state with other states. The first dimension is concerned with the choice of research fields, whereas the second dimension is concerned with the choice of partners' states. A number of quantitative indicators, based on publication counts and coauthorship links of research papers, have been constructed and used to develop research and cooperation profiles of different states. State of the art statistical techniques and computer software have been used in this analysis.

Several colleagues at National Institute of Science, Technology and Development Studies (NISTADS) have helped me in different phases of the study, right from conceptualization through data collection and analysis, up to the final processing of the manuscript. I am grateful to Ms. Madhu Sheopuri for data analysis, graphics and preparation of manuscript through several drafts.

I am particularly indebted to Dr. Ashok Jain, Director, NISTADS and his colleagues for intellectual, moral and infrastructural support, without which this study could not have been undertaken.

Finally, I wish to express my gratitude to Dr. A. Lahiri, Adviser and Ms. Kamini Mishra, Principal Scientific Officer, Department of Scientific and Industrial Research for their active support and encouragement.

(P.S. Nagpaul)
Principal Investigator
25.03.1998

CONTENTS

0 Executive Summary

Regional distribution of science and cooperation among different regions are important issues of science policy. In this study, we have analyzed the patterns of research output and cooperation links among 28 states of the Indian union (including Union territories), using bibliometric indicators based on counts of publications and coauthorship links.

Interstate cooperation is examined along two dimensions:

(i) Cooperation activity of a state in different fields.

(ii) Cooperation links of a state with other states.

The first dimension is concerned with the choice of research fields for cooperation, whereas the second dimension is concerned with the choice of partner states.

Methodology

The data were taken from the database created for the project *Science Beyond Institutional Boundaries*. The database is derived from the *Science Citation Index* (CD-ROM version). It includes the following types of documents: *Articles*, *Reviews*, *Notes* and *Letters* (hereafter designated as *Articles*) signed or cosigned by authors based in India. The articles were classified into 128 subfields, which in turn were classified into eleven macrofields: *Mathematics* (MAT), *Physics* (PHY), *Chemistry* (CHM), *Biology*

(BIO), *Earth & Atmospheric Science* (EAS), *Agriculture & Food Science* (AGR), *Clinical Medicine* (CLI), *Biomedical Research* (BIM), *Engineering & Technology* (ENT), *Computer Science* (COM), *Materials Science* (MTL). The articles which could not be assigned to any particular field were treated as unidentified.

The following indicators have been constructed for inter – field and interstate comparisons:

$$\text{Domesticity Index } (Dol) = \frac{\text{No. of articles cosigned by authors from two or more states}}{\text{No. of all articles}} \times 100$$

$$\text{Internationalization Index } (Inl) = \frac{\text{No. of internationally coauthored articles}}{\text{No. of all articles}} \times 100$$

General Overview of the Data

(a)	No. of articles	52482
(b)	No. of articles cosigned by authors from two or more states	2987
	Domesticity Index (%)	5.69
(c)	No. of interstate cooperation links	7033
	No. of links per coauthored article	2.35
(d)	No. of internationally coauthored articles	6487
	Internationalization Index (%)	12.36
(e)	No. of international cooperation links	8503
	No. of links per internationally coauthored articles	1.31

The number of internationally coauthored articles exceeds that of interstate coauthored articles by 117%, but the number of international links exceeds that of interstate links by only 20%. These results imply that interstate cooperation is less frequent than international cooperation, but when it takes place, it tends to involve multilateral links.

There are strong inter – field differences in the levels of publication output and cooperation links, which may be visualized from Figure 1.

Certain fields have greater 'attraction' (or potential) for cooperation far in excess of their size, whereas as some other fields have much less attraction. *Earth & Atmospheric Science* has the highest level of cooperation (measured through *Domesticity Index*) followed by *Physics*; *Chemistry* has the lowest level of cooperation.

There are also strong interstate variations in the levels of publication output and cooperation links.

Figure 2 depicts the output of articles and cooperation links of 24 states. It can be easily seen that the rankings of states on counts of articles, interstate links and international links are about the same but not concordant. For example, Maharashtra has the highest number of articles, but not the highest number of interstate and international links. West Bengal ranks third on counts of articles, but it ranks fifth on those of interstate as well as on international links.

Figure 3 depicts the *Domesticity* and *Internationalization Indices* of different states. The values of *Domesticity Index* are always greater than or equal to *Internationalization Index*. Smaller states have higher values of *DoI* and *InI*.

There are also strong variations among the states in the emphasis given to different fields in their research agenda (as revealed through the distribution of publications *in different* fields) as well as in their cooperation links.

Figures 4 and 5 show the distribution of articles and cooperation links of different states. For certain states, research and cooperation profiles are similar, whereas for some other states, the profiles are quite different. For example, Haryana gives greater emphasis to *Biology* and *Agriculture* in research, whereas it gives much greater emphasis to *Physics* in interstate cooperation.

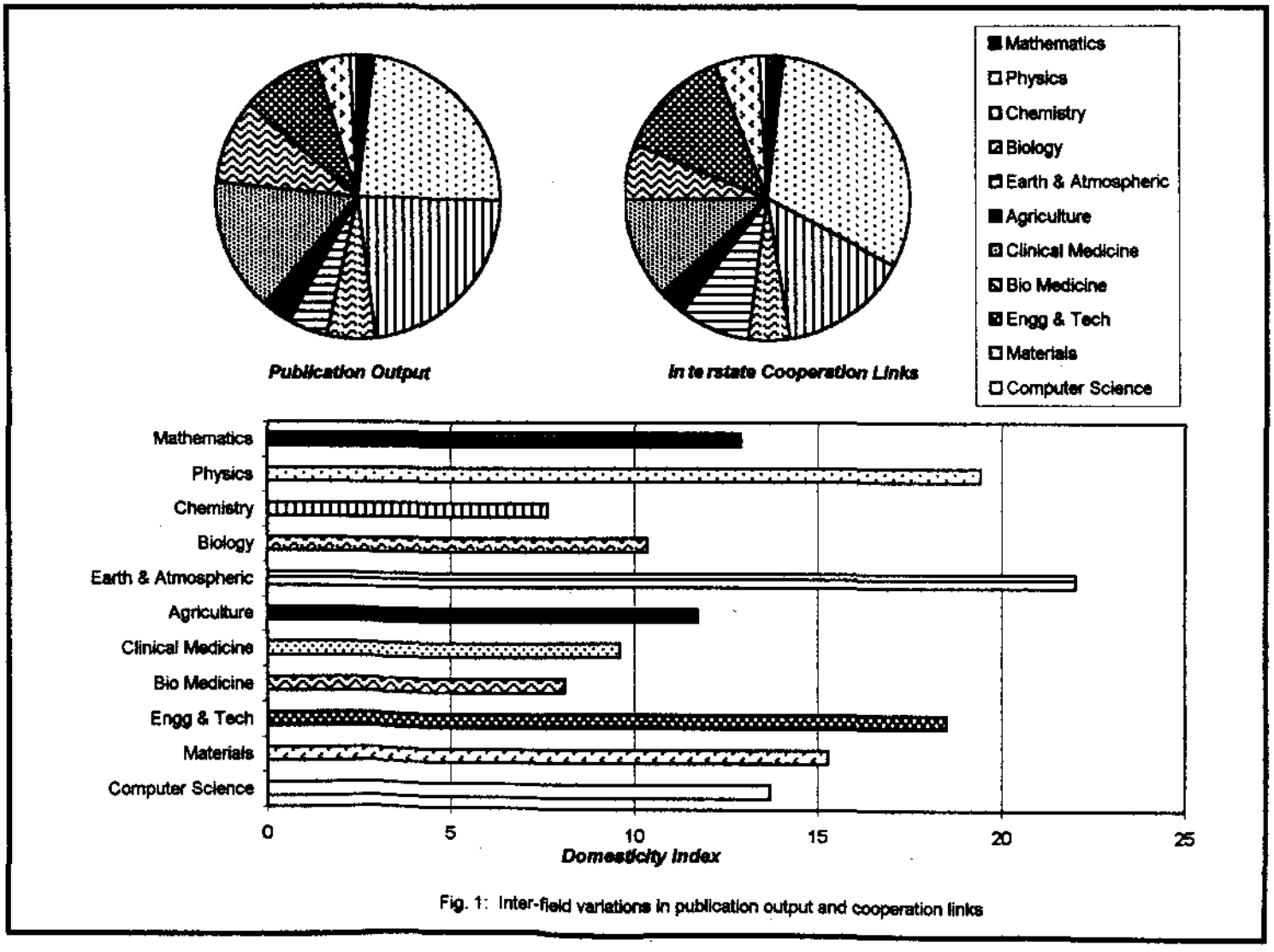
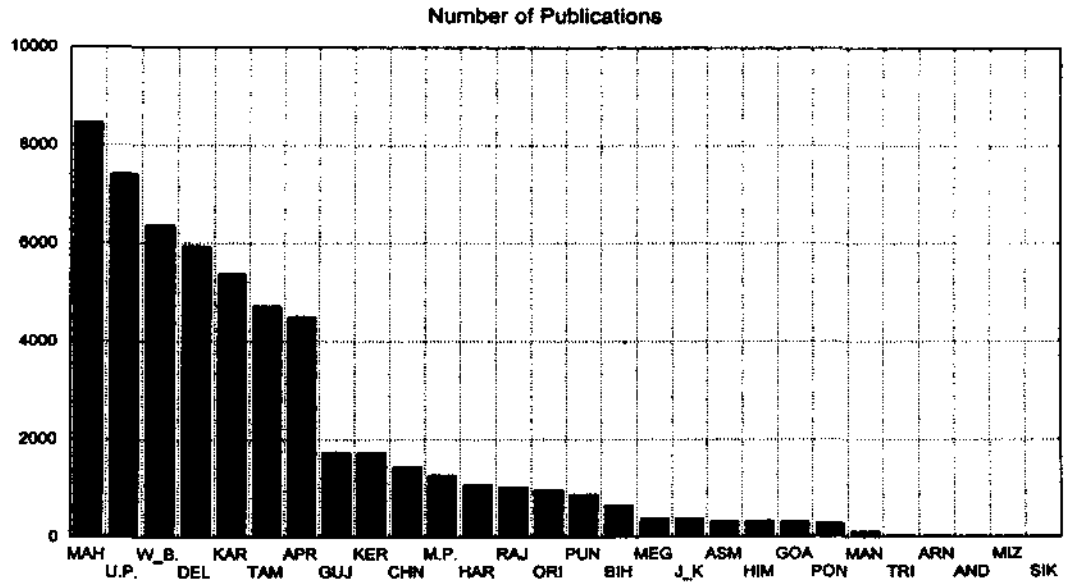


Fig. 1: Inter-field variations in publication output and cooperation links



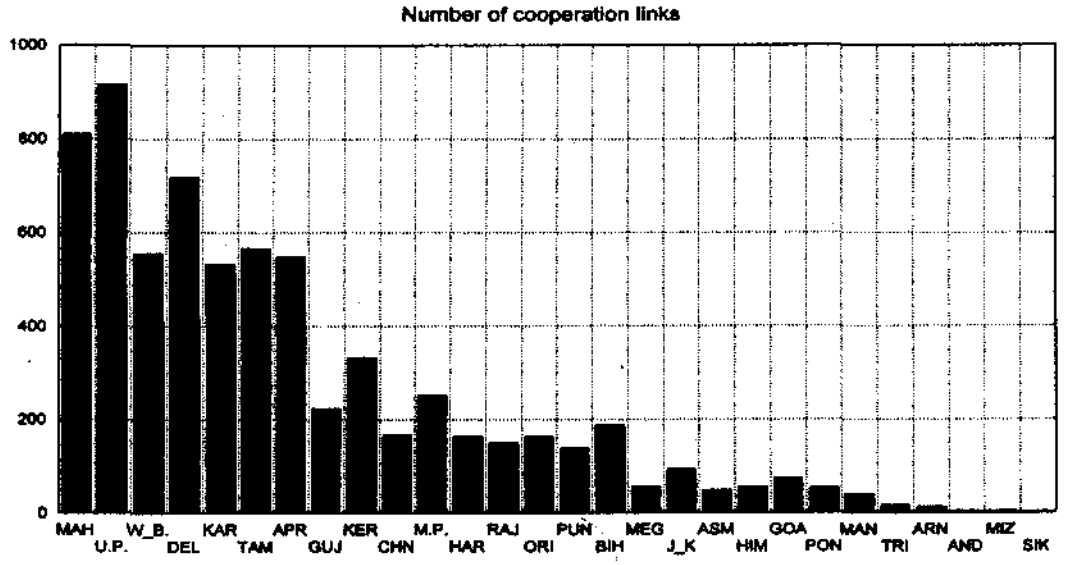


Fig. 2: Publication output and cooperation links of different states

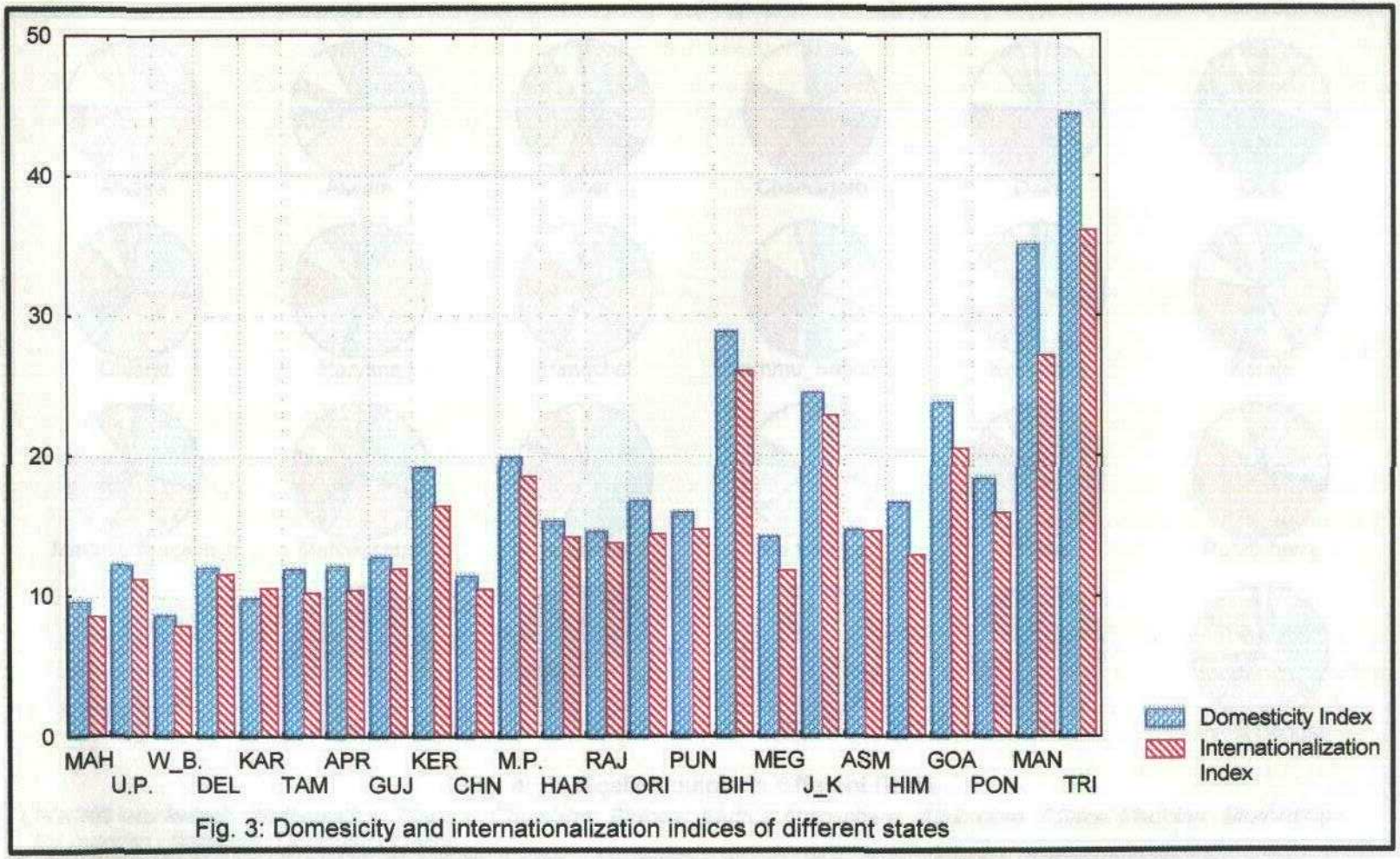


Fig. 3: Domesicity and internationalization indices of different states

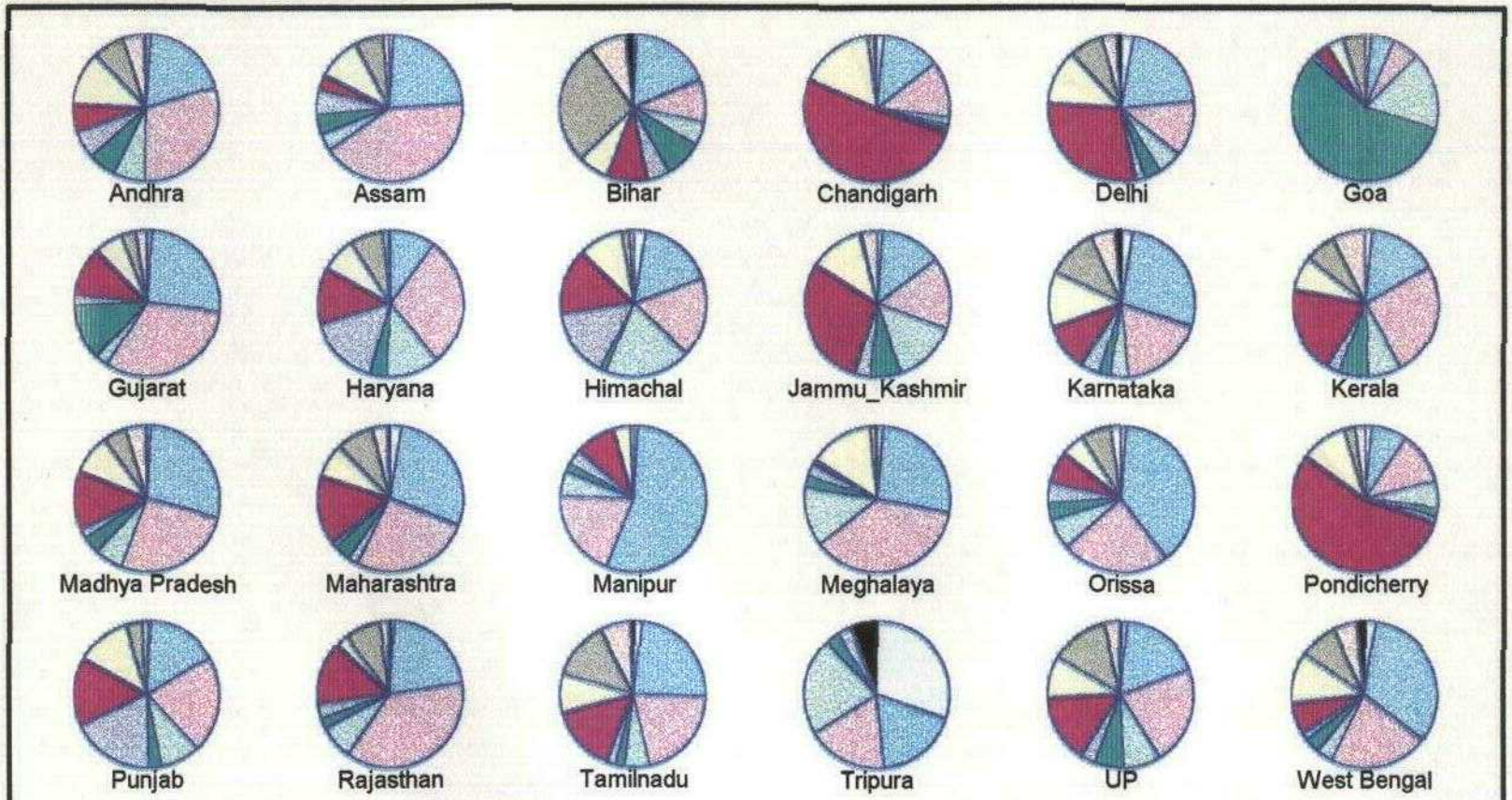


Fig. 4: Publication output in different fields

LEGEND (clockwise): Mathematics, Physics, Chemistry, Biology, Earth & Atmosphere, Agriculture, Clinical Medicine, Biomedicine, Engineering, Materials, Computer Science,

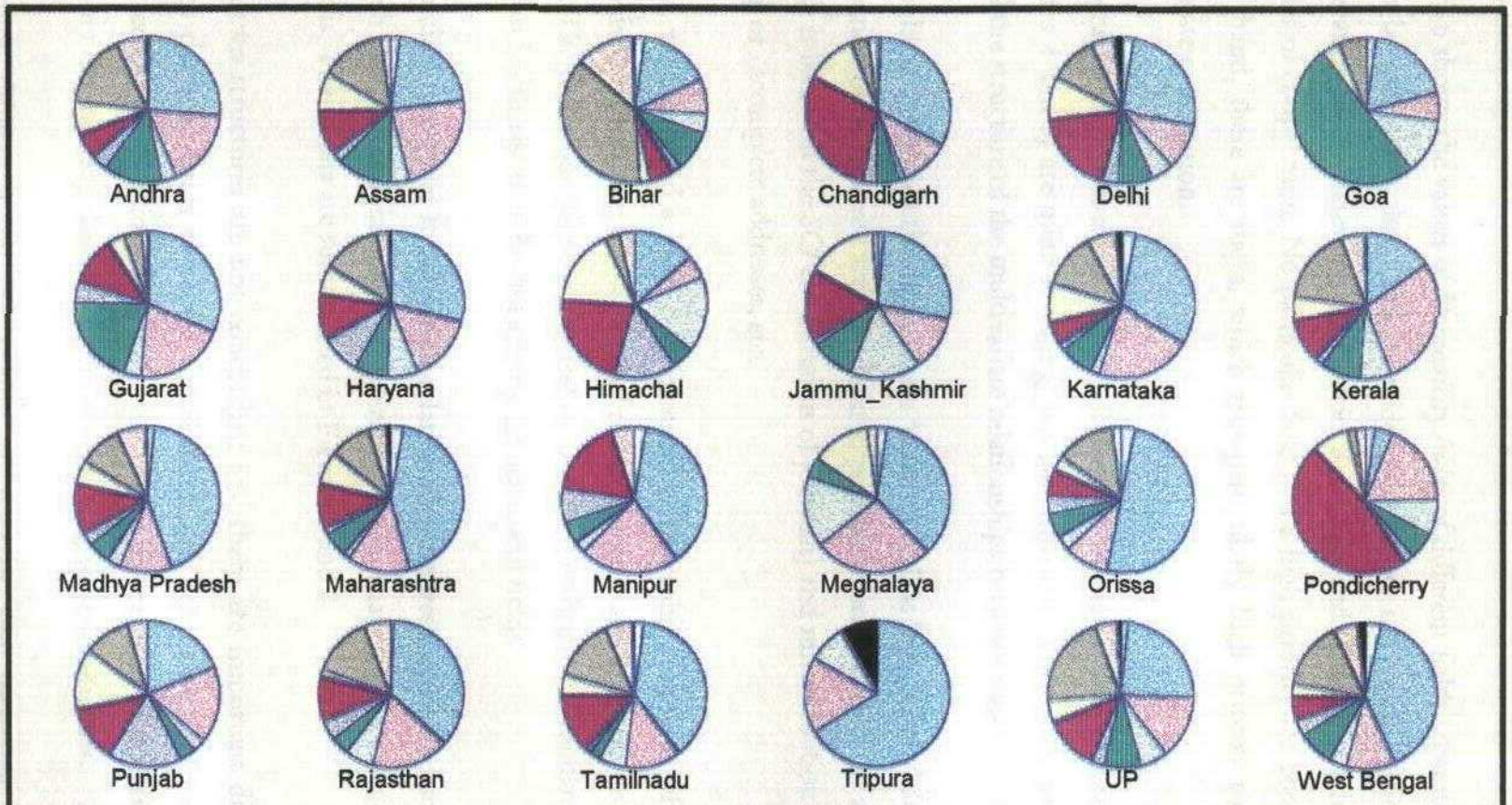


Fig. 5: Interstate cooperation in different fields

LEGEND (clockwise): Mathematics, Physics, Chemistry, Biology, Earth & Atmosphere, Agriculture, Clinical Medicine, Biomedicine, Engineering, Materials, Computer Science,

Figure 6 shows the values of *Domesticity Index* of different fields separately for each state. It can be easily seen that there are wide variations in the choice of fields for interstate cooperation. Some states (e.g. Tamilnadu, Karnataka and West Bengal) have relatively flat profiles of cooperation. No particular field gets a high priority for cooperation. On the other hand, there are states, which give particularly high priority to a few fields for interstate cooperation.

The graphical presentations of correlations of 24 states with eleven scientific fields (Figures 4 and 5) are quite revealing, but also time consuming. Moreover, they do not reveal the structure of the multivariate relationships between states and fields.

It should be noted that the data contain 'noise' as well as 'redundancy' due to overlapping attribution of coauthored articles to states, possible misclassification of articles into fields (which is based on the *SCI* classification of journals) and misattribution of articles due to wrong or incomplete addresses, etc.

Hence, we have used a high – performance cartographic technique of Correspondence Analysis for comparing the patterns of research output and cooperation links of different states. The technique filters out noise, minimizes the effect of redundancy and highlights the most legitimate correlations among the states and fields.

The multidimensional structures of relationships between states and scientific fields for research output and interstate cooperation were analyzed through Correspondence Analysis. The results are summarized in Figures 7 and 8.

These two structures are not concordant and there are important differences, which implies that the fields preferred for research are not necessarily the same as those preferred for cooperation. It appears that the states are using cooperation as a strategy for either augmenting their strengths or rectifying their weaknesses.

Important differences in the profile of research and interstate cooperation are summarized below. For other states, the differences are trivial.

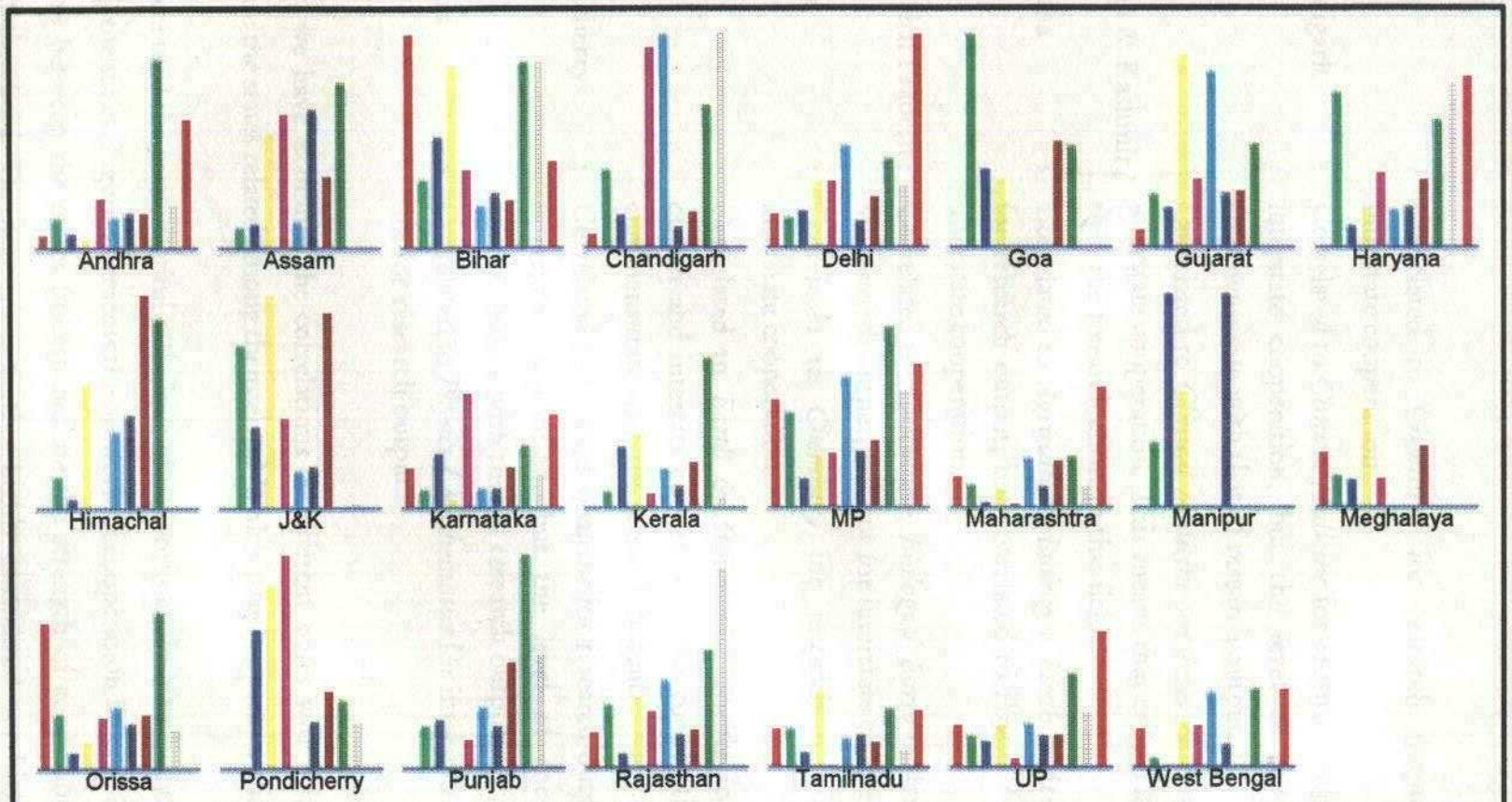


Fig. 6: Domesticity indices of different fields

LEGEND (left to right): Mathematics, Physics, Chemistry, Biology, Earth &Atmosphere , Agriculture, Clinical Medicine, Biomedicine, Engineering, Materials, Computer Sci,

Assam	:	Correlated to *Chemistry* for research output but not for interstate cooperation.
Chandigarh	:	Correlated to *Clinical Medicine* for research output as well as for interstate cooperation, but the level of cooperation is not commensurate with that of research output.
Delhi Jammu & Kashmir	:	Correlated to *Clinical Medicine* for research output but not for interstate cooperation. This means that cooperation effort is less than the research effort in this field.
Haryana	:	Correlated to *Agriculture, Biology / Earth & Atmospheric Science* for research output, but correlated to *Physics / Mathematics* for interstate cooperation.
Himachal Pradesh	:	Correlated to *Agriculture, Biology / Earth & Atmospheric Science* for research output, but not for interstate cooperation.
Orissa	:	Correlated to *Chemistry* for research output but not for interstate cooperation.
Goa	:	Correlated to *Earth & Atmospheric Science* for both research output and intestate cooperation, but cooperation effort is not commensurate with the research output.
Pondicherry	:	Correlated to *Clinical Medicine* for research output as well as for interstate cooperation, but the level of cooperation is not commensurate with that of research output.
Tripura	:	Correlated to *Physics / Mathematics* for interstate cooperation but not for research output.

So far, we have examined the correlations of different states with scientific fields. But how are the states related among themselves? Which state cooperates with whom?

We have used the mathematical technique of networks analysis to analyze the mutual ties among the states. Figure 9 presents the network of cooperation links of 28 states, whereas the arcs between the nodes (states) indicate the strength of cooperation links above a certain threshold. The network is neither highly centralized nor highly decentralized. Moreover, none of the states dominates the network.

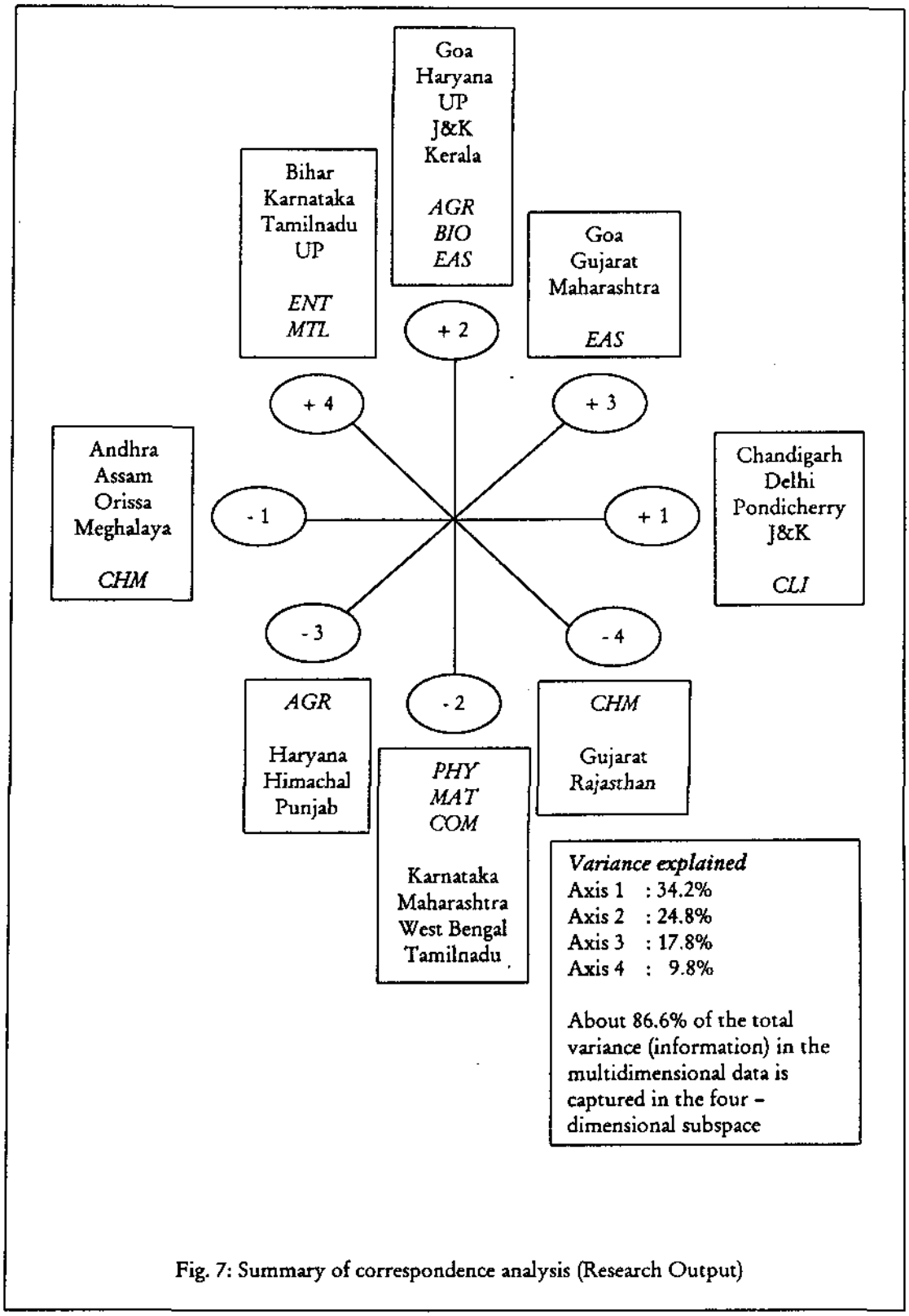


Fig. 7: Summary of correspondence analysis (Research Output)

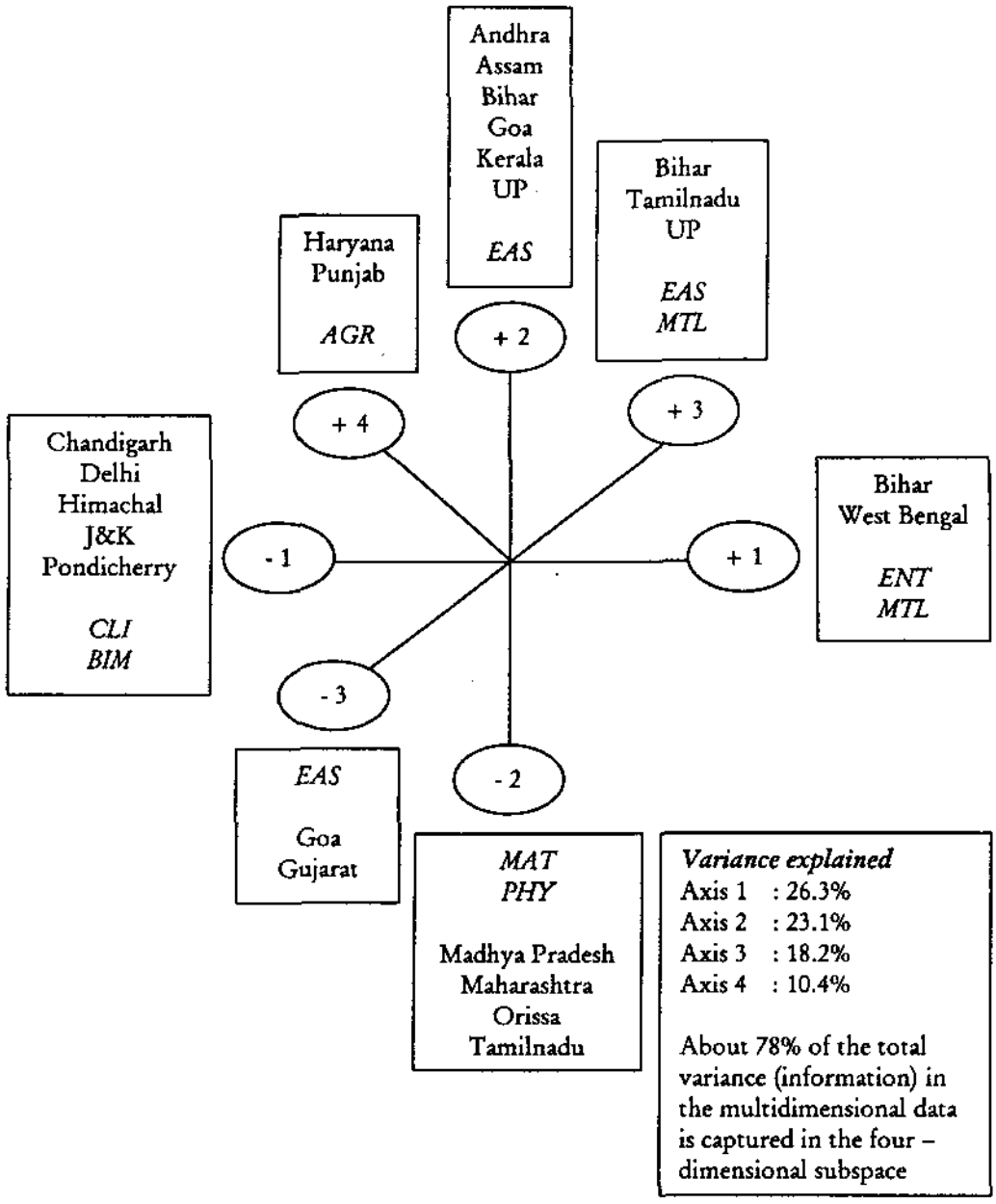


Fig. 8: Summary of correspondence analysis (Interstate Cooperation)

It can be easily seen that the central region of the network which is occupied by UP, Bihar, Delhi, Rajasthan, Gujarat, MP, Maharashtra, Karnataka and West Bengal is densely packed. The incidence of mutual connections in the region is greater than that in the other parts of the network. The subgraph occupied by the Eastern states is rather sparse, indicating lower incidence of mutual connections among these states.

The network presented in Figure 9 is quite revealing as it provides a synoptic view of state - by - state relationships. But the network is quite complex and difficult to comprehend. The network comprises 28 nodes and 170 arcs.

Figure 10 presents a reduced graph in which the states have been clustered into 'blocks', according to the similarity of their relationships with other states. The reduced graph is called a 'block model'.

Figure 10 indicates a divide between the Eastern region and the rest of India. Why are the Eastern states isolated? Eastern states are isolated from the national network, not because they do not want to cooperate with other states, but because they are to small to effectively participate in the national network of science. This implies that the strengthening of scientific potential of these states is a necessary pre - condition for their integration into the national network of science.

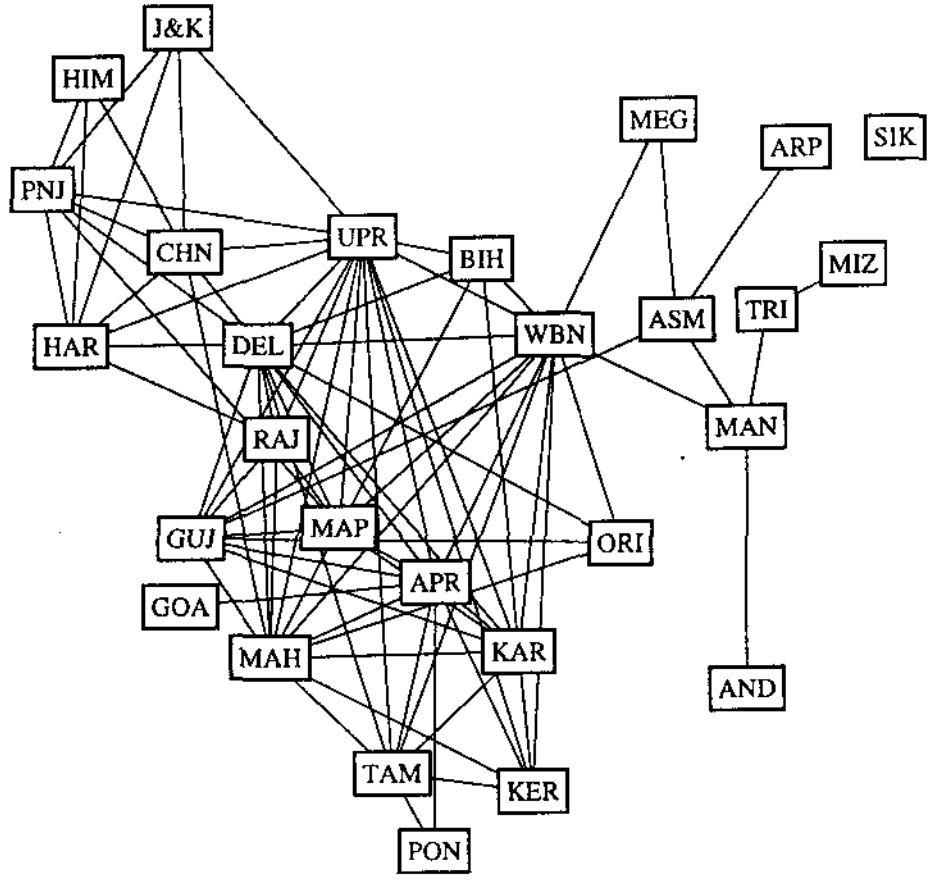


Fig. 9: Network of interstate cooperation

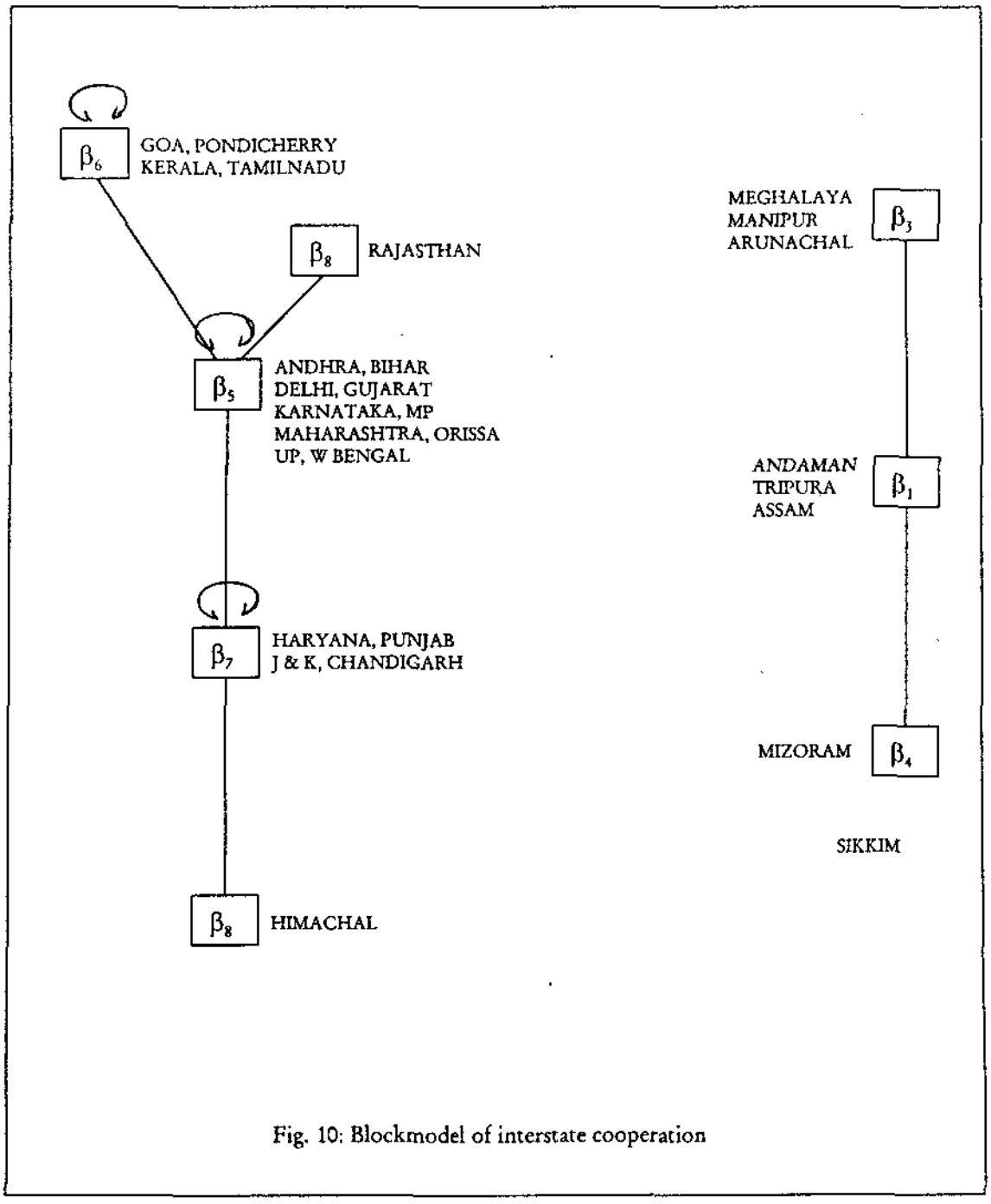


Fig. 10: Blockmodel of interstate cooperation

1 Introduction

The union of India comprises 28 political regions, called *states*[1]. These states differ in respect of geographical area, size of population and level of social and economic development. These states also differ in respect of scientific potential. Till now, no study has been carried out on the regional distribution of science in India and cooperation links between the regions.

This study seeks to examine the volumes and patterns of research output and cooperation among the Indian states during the five year period: 1990 - 1994, using bibliometric indicators (i.e. publications in refereed scientific journals). Its specific concerns are:

1. What is the extent of interstate and international cooperation of Indian states and how does it vary between the states?
2. What are the similarities and differences among the states in the emphasis given to different scientific fields in their research and development work?
3. What are the similarities and differences among the states in the choice of scientific fields for interstate cooperation?
4. Are the fields that are prominent in the research profiles of the states the same as those that are prominent in the profiles of interstate cooperation?
5. What is the structure of the network of interstate cooperation? Is the network centralized or decentralized? Which are the states that dominate the network and which are the states that reside in the periphery of the network?

[1] Here, the term *States* includes *Union territories*.

2 Methodology

Measurement of Collaboration

In this study, scientific collaboration is measured by coauthorships, which signify a formal acknowledgment of joint research. Here, the principal assumption is that the writing of coauthored articles is a manifestation of a fairly active linkage between researchers, closer and more active than the exchange of materials and information or sharing of research facilities. However, it is important to note that bibliometric measures under-estimate the level of mutual collaboration. As pointed out by Luukkonen[1] *et al.* all collaborative efforts do not necessarily end up in coauthorships. Further, it is quite possible that researchers who had collaborated extensively may still write separately authored articles; particularly in the case of large teams, self-contained units in different states (or institutions) may each publish their own parts of the research project.

Interstate coauthorship is defined in terms of articles cosigned by authors from different states. These coauthorships are used to identify relationships by means of institutional affiliation of the authors and not by means of their place of birth. An important, but controversial, issue in coauthorship analysis is how to assign credit of a coauthored article to a unit (state or institution). Since the objective of the study is not coauthorships *per se*, but the interstate relationships which they pattern, we have adopted the 'whole count' method in preference to 'fractional counting'. Here, we assume that a contact between any two states is always a fixed single unit, which does not vary with the number of states involved in a coauthored article. A contact is a link

that always has the same value between any two states, irrespective of the number of participants. For example, if an article has authors from three states (A,B,C), three coauthorship linkages would occur: A ↔ B, B ↔ C, A ↔ C. If the number of authors from a given state exceeds one, the collaboration with that state is registered only once. In other words, a link cannot be valued as one-third in one collaboration and one-fourth in another at macro-level analysis. Whatever the number of scientists, institutions or states involved in a coauthorship, one link is always established between each pair of participating states.

Choice of Database

Despite certain limitations, which are amply discussed in the literature, *Science Citation Index (SCI)* is by far the most important database for scientometrics research (Carpenter & Narin[2]. It is the only database which includes the corporate addresses of all the authors of an article, whereas other databases give the corporate address of only the first author.

The set of articles signed or cosigned by Indian authors listed in the *SCI* database was downloaded from the CD-ROM's for five indexing years: 1990 -1994. The downloaded data comprises more than 54,000 records of publications. Each record comprises the following elements:

- Names of all authors.
- Source: Title of the journal, volume and year of publication, page numbers.
- Title of the publication.
- Number of references cited.
- Type of publication: Article, research note, review, etc.
- Addresses of all authors in the following format: Name of the institution or university; name of the department; name of the city; name of the country.

The downloaded data is not amenable to retrieval or statistical analysis unless it is transformed into a database.

Initially, we used the UNESCO software *CDS-ISIS* for transformation of the downloaded data into a useable database. This software was particularly chosen in view of its flexible format and interface with a statistical software *IDAMS* (Internationally Developed Data Analysis and Management Software Package) developed by UNESCO. But due to certain technical limitations of the software and logistic reasons, we had to abandon the idea of using *CDS-ISIS*. Instead, we used the commercially available software *FOXPRO*, which has interface with the well - known statistical software *SPSS* (Statistical Package for Social Sciences). *FOXPRO* has also a limitation. It has a fixed format, which means that one has to define as many variables as the number of addresses in the record which has the largest number of addresses. Some of the records had more than 100 coauthors and therefor more than 100 addresses (in one case, there were 300 addresses).

The transformation of 54,000 records into *FOXPRO* format would roughly require diskspace of more than 400 MB. This problem was overcome by partitioning of the downloaded data into two files: one in which the number of addresses did not exceed 10. The second file had only 128 records. It was processed as follows: Different countries and different institutions were identified and coded manually prior to computerization.

Both the datafiles were further processed to filter out documents which do not indicate research output. *ISI* classifies the documents into twelve categories:

1. Article	7. Letter
2. Biographical Item	8. Meeting Abstract
3. Book Review	9. Note
4. Correction	10. Reprint
5. Discussion	11. Review
6. Editorial	12. Software Review

Obviously, some of these categories do not represent research output and their inclusion in the datafiles will distort the results of bibliometric analysis. Computer Horizons Inc. (*CHI*) database (which is derived from the *ISI* database) includes articles, notes and reviews.

Articles are the basic means of communicating new scientific knowledge. *CHI* includes notes, because shorter publications in many important journals are classified as 'notes' and these are an important part of the scientific literature. It can be argued that a review does not generally constitute an original piece of research, but rather a synthesis of work done by others. It is not so much an indication of research output as of scholarship. The counter argument is that scholarship is a form of research. Moreover, review authors are generally regarded as authorities in their field. Hence, a review article does provide information on the relative standing of different countries, states or institutions.

'Meeting abstracts' account for 18 – 20% of the *SCI* covered documents. These are not included in *CHI* for the following reasons:

(i) To avoid double counting. Many scientific results initially presented at meetings are subsequently published as journal articles.

(ii) Review procedure for such contributions are less rigorous than for articles.

CHI also does not include editorials and letters as they do not normally report substantive research contributions.

The Hungarian database (*ISSRU*) which is also derived from the *ISI* database, includes articles, notes, reviews and letters. *ISSRU* contends that although all the anecdotic arguments on the 'originality', 'basicity', 'fundamentality', 'importance' or 'scholariness'

of one or the other type of journal documents contain a certain grain of reliability, it is advisable to use a more homogeneous and universal criterion for inclusion or exclusion of certain types of documents. One such criterion is 'Citation Impact'. As such, it seems desirable, when constructing indicators of national or regional scientific output, to include in the count all publication types which are cited at an appreciable level. The citation rate of letters is comparable to or in some cases even higher than that of articles. Further, in most of the Commonwealth countries, including India, the production of letters amounts to a considerable part of the total scientific output. In the case of India, letters constitute about 4% of all publications.

We have followed *ISSRU*'s procedure and included articles, notes, reviews and letters in the construction of datafiles for mapping of cooperation links of Indian science. Henceforth, these four types of documents would be referred as *Articles*.

Data cleaning

The names of institutions listed in the *SCI* database are not standardized. The large variety of names referring to the same research institution encountered in the address lists were unified semi-automatically. In several cases, the name of the state was not given or not evident from the address of the author. We had to use the *Postal Pincode Directory* to identify the state.

Classification of articles

Classification of articles into fields or subfields is a neuralgic point of scientometrics research (Schubert & Braun[3]). Classification of more than 50,000 articles is obviously an uphill task that would require several analysts with familiarity in different disciplines. Hence, we have adopted the procedure developed and tested by Computer Horizons Inc. (*CHI*). According to this procedure, the journals are classified into subfields, subfields into fields, and each article is classified into the field and subfield of the journal in which it is published. This methodology is based on the assumption that science journals are the fundamental units of assessment. Although exceptions are

there, science journals, as a rule, encompass definite research areas (frequently a single 'paradigm') and also a standard of quality guaranteed by the editorial gatekeeping process. Therefore, it seems justified to assign a set of publications to subject fields on the basis of the field classification of journals.

The starting point of our classification schema is the *SCI* journal classification system. *SCI* classifies the journals into subfields, using a combination of techniques — journal – to – journal citation patterns, keyword analysis and user feedback (Katz & Hicks[4]). A major limitation is that about 20% of all journals are classified into more than one subfield. Further, 62 journals are classified as 'Multidisciplinary' as they include articles from diverse fields. Journals like *Nature, Science, Current Science, Journal of Scientific and Industrial Research* belong to this category. However, this does not mean that these journals cover only multidisciplinary research. It only means that their field is not identified.

There is, however, no standard classification of subfield categories into macrofield categories. This is primarily due to the intersections of subfield categories. Therefore any attempt to develop a standard classification system is bound to be somewhat arbitrary. Theoretically, one can agglomerate subfield categories into macrofield categories through cluster analysis or factor analysis. R. Barre[5] has classified 107 research fields in the *PASCAL* database into 13 macrofields, using cluster analysis.

In this study, we have classified the subfields into the following macrofields:

1.	Mathematics (MAT)	7.	Clinical Medicine (CLI)
2.	Physics (PHY)	8.	Biomedical Research (BIM)
3.	Chemistry (CHM)	9.	Engineering and Technology (ENT)
4.	Biology (BIO)	10.	Computer Science (COM)
5.	Earth & Atmospheric Science (EAS)	11.	Materials Science (MTL)
6.	Food & Agriculture (AGR)	12.	Multidisciplinary (MUL)

Analyses

A number of indicators have been constructed from coauthorship data, which are used to analyze the patterns of research output and interstate cooperation links:

Domesticity Index (*DoI*) measures the incidence of interstate cooperation links of a state compared to its publication output.

$$DoI = \frac{\text{Number of interstate links}}{\text{Number of articles}} \times 100$$

Internationalization Index (*InI*) measures the incidence of international cooperation links of a state compared to its publication output.

$$InI = \frac{\text{Number of international links}}{\text{Number of articles}} \times 100$$

Affinity Index

Affinity Index (*AFI*) is a measure of the amount of scientific cooperation between a given state A and another state B compared to the total cooperation of the given state with the rest of the country (CNT). *AFI* is therefore the number of *COP*'s between A and B divided by the total *COP*'s A has with the rest of the country. It indicates the scientific affinity of A toward B (A→B).

$$AFI\,(A \rightarrow B) = \frac{COP\,(A \leftrightarrow B)}{COP\,(A \leftrightarrow CNT)} \times 100$$

Similarly, affinity of B towards A (B→A) is computed as follows:

$$AFI\,(B \rightarrow A) = \frac{COP\,(B \leftrightarrow A)}{COP\,(B \leftrightarrow CNT)} \times 100$$

Affinity index is used to find how B situates in A's cooperation activity with the country. It also reciprocally finds how A situates in B's cooperation activity with the country.

Two sets of analyses have been carried out:

(i) Univariate analysis to reveal the profiles of research output and cooperation links of individual states.

(ii) Structural analysis to reveal

  (a) the structure of research output i.e. the structure of the multidimensional system of relationships of different states and eleven macrofields.

  (b) the structure of interstate cooperation i.e. the structure of of the multidimensional system of relationships of different states and eleven macrofields.

  (c) the network of mutual cooperation mutual among the states.

Univariate and multivariate statistical techniques are used for description and analysis of the data. Main trends are depicted by means of infographics and algorithmic mapping.

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3 Profiles of Research and Interstate Cooperation

This chapter examines the volume and patterns of research output and cooperation among the Indian states (including Union territories), using bibliometric indicators. Its specific concerns are:

1. What is the extent of interstate and transnational cooperation of Indian states and how does it vary between the states?
2. What are the similarities and differences among the states in the emphasis given to different scientific fields in their research and development work?
3. What are the similarities and differences among the states in the choice of scientific fields for interstate cooperation?
4. Are the fields that are prominent in the research profiles of the states the same as those that are prominent in the profiles of interstate cooperation?

General Overview of the Data

During the five – year period: 1990 – 1994, India had published 52,482 articles (*Articles*, *Reviews*, *Notes* and *Letters*) in the mainstream journals covered by the *Science Citation Index*. Of these, 2,987 articles (5.69%) were cosigned by authors from different states involving 7,033 interstate cooperation links, which means 2.35 links per interstate coauthored article. Further, 6,487 articles were cosigned by authors from different countries, indicating an aggregate of 8,503 transnational cooperation links, which means 1.31 links per internationally coauthored article.

The distribution of articles, interstate cooperation links and transnational cooperation links among the states is highly skewed. Five states (Maharashtra, UP, West Bengal, Delhi and Karnataka) account for about 63.9% of all articles, 50.2% of all interstate links and 46.4% of all transnational links of Indian science.

The incidence of internationally coauthored articles exceeds that of interstate coauthored articles by 117%. But the incidence of international cooperation links exceeds that of interstate links by only 20%. These results imply that interstate cooperation is less frequent than international cooperation, but when it takes place, it tends to be multilateral rather than bilateral.

Table 3.1 presents the data on the output of articles and cooperation links of 28 states. It can be easily seen that the ranking of states on counts of articles, interstate links and transnational links is about the same, but not concordant. For example, Maharashtra has the highest output of articles, but not the highest number of interstate links or transnational links. West Bengal ranks third on counts of articles, but it ranks fifth on counts of interstate cooperation as well as transnational cooperation links.

Using the counts of cooperation links, we have constructed two indicators for assessing and comparing the cooperation efforts made by different states within and outside the country: *Domesticity Index* and *Internationalization Index*.

Domesticity Index (*DoI*) measures the incidence of interstate cooperation links of a state compared to its publication output.

$$DoI = \frac{\text{Number of interstate links}}{\text{Number of articles}} \times 100$$

Table 3.1
Publication output and cooperative links of different states (1990 – 1994)

States	*No. of Articles*	*No. of Interstate links*	*Domesticity Index*	*No. of Transnational Links*	*Internationalization Index*
Maharashtra	8453	809	9.57	728	8.61
Uttar Pradesh	7409	915	12.35	840	11.34
West Bengal	6370	555	8.71	509	7.99
Delhi	5937	718	12.09	693	11.67
Karnataka	5375	533	9.92	573	10.66
Tamilnadu	4723	566	11.98	487	10.31
Andhra Pradesh	4508	548	12.16	473	10.49
Gujrat	1732	223	12.80	208	12.01
Kerala	1729	332	19.20	285	16.48
Chandigarh	1441	165	11.45	152	10.55
Madhya Pradesh	1259	251	19.94	234	18.59
Haryana	1060	163	15.38	151	14.25
Rajasthan	1021	149	14.59	141	13.81
Orissa	970	163	16.80	140	14.43
Punjab	866	138	15.94	128	14.78
Bihar	648	187	28.86	169	26.08
Meghalaya	380	54	14.21	45	11.84
Jammu & Kashmir	376	92	24.47	86	22.87
Assam	327	48	14.68	48	14.68
Himachal Pradesh	324	54	16.67	42	12.96
Goa	307	73	23.78	63	20.52
Pondicherry	288	53	18.40	46	15.97
Manipur	114	40	35.09	31	27.19
Tripura	36	16	44.44	13	36.11
Arunachal Pradesh	27	13	48.15	14	51.85
Andaman	14	3	21.43	2	14.29
Mizoram	7	3	42.86	4	57.14
Sikkim	6	2	33.33	4	66.67

Internationalization Index (*InI*) measures the incidence of international cooperation links of a state compared to its publication output.

$$InI = \frac{\text{Number of international links}}{\text{Number of articles}} \times 100$$

The values of *DoI* and *InI* are also given in Table 3.1.

Generally speaking, scientifically larger states rank low on *Domesticity Index* as well as on *Internationalization Index*, and smaller states rank high on both these indices.

Research Output

Table 3.2 presents the data on publication output of different states in eleven macrofields (*Mathematics*, *Physics*, *Chemistry*, *Biology*, *Earth & Atmospheric Science*, *Food & Agriculture*, *Clinical Medicine*, *Biomedical Research*, *Materials Science* and *Computer Science*). It can be easily seen that all the fields are not similarly represented in different states. There are considerable interfield differences, depending upon the objectives and research competence of institutions located in the states. However, we cannot comprehend these differences, since raw counts of publications are confounded by the size of the state and the size of the subject field. To overcome this problem, several researchers have used an index, called *Activity Index* (*AI*), initially proposed by Frame (197) and subsequently used by Schubert & Braun *et al.* (1986), Carpenter *et al.* (1988), and Nagpaul & Pant (1993).

Table 3.2
Research output in different fields

States	*MAT*	*PHY*	*CHM*	*BIO*	*EAS*	*AGR*	*CLI*	*BIO*	*ENT*	*COM*	*MTL*
APR	46	824	1321	301	267	263	275	505	308	20	201
ASM	3	73	132	12	14	17	11	31	20	0	4
BIH	5	111	60	34	52	31	57	43	170	10	52
CHN	22	175	174	24	14	8	708	229	20	1	6
DEL	158	1158	705	306	202	110	1677	681	424	52	184
GOA	4	15	17	50	168	3	10	11	14	0	0
GUJ	17	422	541	49	205	34	185	103	55	3	38
HAR	2	100	301	121	40	165	131	81	78	5	10
HIM	8	49	52	57	4	45	43	29	5	0	3
J&K	4	46	55	49	24	12	100	41	2	0	12
KAR	119	1373	918	205	129	215	529	612	554	74	267
KER	23	253	416	121	112	46	325	123	114	1	120
M.P	10	344	331	78	47	23	161	107	63	6	52
MAH	203	2320	2167	176	303	90	1254	609	692	50	253
MNP	1	62	22	6	2	4	10	4	0	0	1
MEG	5	98	136	47	10	10	4	53	5	0	1
ORI	11	367	229	64	36	42	70	49	64	2	20
PON	4	22	32	17	5	4	153	29	7	0	6
PUN	6	133	184	76	25	158	130	100	31	0	10
RAJ	8	211	367	74	23	30	138	26	77	6	17
TAM	79	1073	968	253	90	93	684	389	584	46	299
U.P	85	1274	1570	589	464	244	1086	649	908	37	229
W.B	143	2075	1400	239	197	116	452	693	529	123	317
MIZ	0	2	3	0	0	0	1	0	0	0	0
SIK	0	0	0	2	1	2	0	1	0	0	0
AND	0	0	0	7	3	1	3	0	0	0	0
ARN	0	4	12	3	0	0	0	4	4	0	0
TRI	10	6	6	7	1	1	0	0	0	2	0

Activity index is computed as follows:

$$AI(i,j) = \frac{n_{ij} / n_{io}}{n_{oj} / n_{oo}} \quad \text{....(1)}$$

where

i indexes the rows (states) and j indexes the columns (research fields) in the data matrix;

n_{ij} = number of publications by state i in field j.

n_{io} = number of publications by state i in all fields.

n_{oj} = number of publications by all states in field j.

n_{oo} = total number of publications by all states in all fields.

Activity index indicates whether a particular field is under-represented or over-represented in a given state.

The value of $AI = 1$ implies that the research activity of a given state in the field corresponds precisely to the average of all states (*i.e.* the national average) in that particular field *i.e.* average activity. $AI > 1$ reflects higher than average activity and $AI < 1$ lower than average activity. It should be kept in mind that by virtue of the definition of AI, no state can have high activity in all fields.

Van Vianen *et al.* (1990) have pointed out that the validity of activity index is an important problem in the case of small units. The validity of this index depends upon the number of observations per cell (Hinze, 1997). In the present data, extremely high

values of *AI* were obtained for smaller states. The value of *AI* exceeded 3.00 in fourteen cells; in one cell, the value was 16.62.

Equation (1) can be re – written as:

$$AI(i,j) = \frac{\frac{n_{ij}}{n_{io}}}{\frac{n_{oj}}{n_{oo}}}$$

$$= \frac{n_{ij}}{(n_{io} \times n_{oo})/n_{oj}} \qquad \ldots(2)$$

The denominator in this equation is the expected value of a cell, assuming independence between rows and columns of the data matrix. This means that

$$AI(i,j) = \frac{Actual\ value\ of\ cell\ (i,j)}{Expected\ value\ of\ cell\ (i,j)} \qquad \ldots(3)$$

When the number of observations in a cell is small, the ratio between the *actual and* expected number of observations can be extremely high, without being an indictor of a real high activity in that cell. Therefore, the results based on cells with small number of observations should not be used. The expected values of the cells are interrelated and hence too many cells with low expected values corrupt the whole matrix of activity index. Hence, Van Vianen *et al.* (1980) have suggested that the analyzability of the data matrix should be assessed prior to the computation of the activity index.

The function of the activity index is to detect the deviations (positive or negative) from the expected value of a cell. This can be statistically formalized by taking the significance of the difference between the actual and expected values of a cell. This formalization can be achieved through the χ^2 - criterion, which states that fewer than 20% of the cells should have expected values less than 5 and that none of the cells should have expected values less than 1. If a matrix does not comply with these criteria, it should not be used to calculate the activity index, since no valid conclusions can be based on the values of activity indices computed from such a matrix.

Expected values of the data matrix were computed. It was observed that the first criterion was satisfied; only 15.7% of the cells had expected values less than 5. But, the second criterion could not be satisfied; 30 cells had expected values less than 1. Hence, a reduced data matrix excluding four states (Andaman, Arunachal Pradesh, Mizoram and Sikkam) was used for computing the values of activity index. The analyzability of the reduced matrix was checked prior to the computation of the activity index.

The activity index has asymmetrical properties, bounded on one side: Minimum value = 0; Average value = 1; Maximum value $\rightarrow \infty$.

Grupp (1990) has proposed another index - Revealed Literature Advantage (*RLA*) - which is a nonlinear transformation of the activity index. This index is also called (research) specialization index. *RLA* is computed by the following formula:

$$RLA = 100 \tanh (\ln AI)$$

Logarithmic transformation makes the index unbounded on both sides, with (average value = 0). It is bounded by tangent hyperbolic (tanh). Thus *RLA* is symmetrical and bounded on both sides: Minimum value = - 100; Average value = 0; Maximum value = + 100.

Interstate Cooperation

Table 3.3 presents the data on interstate cooperation links of different states in eleven macrofields. The table shows strong inter – field differences in the number of cooperation links, depending upon the nature of the field, the scientific size of the state and its proclivity to forge cooperation links with other states. However, we can not comprehend these differences from the raw counts of cooperation links, which are confounded by the size of the states and the size of the scientific fields in the space of cooperation links. Hence, we have computed an index – called Revealed Cooperation Advantage (*RCA*) – which is computed in the same manner as *RLA*. The analyzability of the matrix was tested prior to the computation of *RCA*.

From the values of *RLA* and *RCA*, the profiles of research specialization and cooperation specialization can be constructed for each state.

Interstate cooperation activity of a state can be visualized along two dimensions:

(i) Cooperation activity of a state in different research fields.

(ii) Cooperation links of a state with other states.

The first dimension is concerned with the choice of research fields for interstate cooperation, whereas the second dimension is concerned with the choice of partner states. The fields emphasized or de – emphasized by a state for cooperation with other states can be identified from the values of Revealed Cooperation Advantage (*RCA*).

We have used another index – Affinity Index (*AFI*) – to reveal the relative importance of different partner states in the cooperation activity of a given state. Affinity index (*AFI*) is computed as follows:

Table 3.3
Interstate links in different fields

States	*MAT*	*PHY*	*CHM*	*BIO*	*EAS*	*AGR*	*CLI*	*BIM*	*ENT*	*COM*	*MTL*
APR	2	131	88	18	66	18	30	37	83	3	32
ASM	1	10	11	2	6	1	5	4	7	0	1
BIH	4	28	14	8	16	3	10	4	67	1	23
CHN	1	48	17	2	8	4	44	17	6	0	3
DEL	19	185	74	36	57	26	137	66	79	13	36
GOA	1	9	3	6	24	0	0	2	3	0	0
GUJ	1	91	60	12	59	14	32	11	12	1	3
HAR	0	46	24	11	12	14	17	10	21	1	4
HIM	0	8	3	10	3	8	13	10	2	0	2
J&K	1	22	10	13	8	1	13	13	0	0	1
KAR	17	179	124	12	44	9	31	50	72	8	37
KER	0	32	61	15	19	4	21	11	36	1	11
M.P	4	108	30	8	12	7	29	13	24	1	16
MAH	22	327	107	12	44	10	78	55	72	7	29
MNI	1	15	9	1	2	3	7	0	0	0	2
MEG	1	16	12	7	2	0	0	6	0	0	1
ORI	5	80	16	5	9	6	10	5	21	0	3
PON	1	2	9	4	3	1	23	4	1	0	1
PUN	0	25	23	4	5	22	17	18	14	0	6
RAJ	1	50	24	9	6	6	14	2	19	0	8
T.N	11	193	65	32	13	6	70	23	71	3	31
U.P	13	207	126	55	73	24	107	45	178	9	42
W.B	20	226	63	23	45	20	31	16	86	11	29
MIZ	0	2	1	0	0	0	0	0	0	0	0
SIK	0	0	0	0	0	1	0	1	0	0	0
TRI	0	8	2	1	0	0	0	0	0	1	0
AND	0	0	0	1	0	0	2	0	0	0	0
ARP	0	3	6	0	0	0	1	0	3	0	0

Affinity Index

Affinity Index (*AFI*) is a measure of the amount of scientific cooperation between a given state A and another state B compared to the total cooperation of the given state with the entire country (CNT). *AFI* is therefore the number of *COP*'s between A and B divided by the total *COP*'s A has with the rest of the country. It indicates the scientific affinity of A toward B (A→B).

$$AFI\,(A \rightarrow B) = \frac{COP\,(A \leftrightarrow B)}{COP\,(A \leftrightarrow CNT)} \times 100$$

Similarly, affinity of B towards A (B→A) is computed as follows:

$$AFI\,(B \rightarrow A) = \frac{COP\,(B \leftrightarrow A)}{COP\,(B \leftrightarrow CNT)} \times 100$$

Affinity index is used to find how B situates in A's national activity with the country. It also reciprocally finds how A situates in B's national activity with the country.

The profiles of research output and cooperation activities of different states are presented below. The profile of each state contains the following data:

Aggregated data and indices:

1. Research output
2. No. of international cooperation links

3. No. of interstate cooperation links
4. Number of partner states, which indicates the 'span' of cooperation activity of a state
5. Domesticity index (*DoI*) which reveals the extent of interstate cooperation in the field, expressed as the number of cooperation links per 100 articles in a field.
6. Centrality Index, which indicates the position of a state in the cooperation network.
7. Internationalization index (*InI*) which indicates the extent of international cooperation, expressed as the number of international cooperation links per 100 articles.

Differentiated data and indices:

1. Research output in different fields
2. No. of interstate cooperation links in different fields
3. Domesticity index (*DoI*) which reveals the extent of interstate cooperation in a field, expressed as the number of cooperation links per 100 articles in the field.

Profiles of States

Andhra Pradesh

Andhra occupies an important position in the scientific map of India; 17 universities and 182 research institutions (in both public and private sectors) are located in this state.

During the five - year period: 1990 - 1994, this state contributed 4,508 articles to the *SCI* - covered journals, constituting about 8.4% of India's total publication output. Andhra is also quite active in interstate and international cooperation in science, which can be visualized from the values of *Domesticity Index* (12.16%) and *Internationalization Index* (10.49%). This state had 548 interstate cooperation links, spanning 22 states — only five states (Andaman, Manipur, Tripura, Mizoram and Sikkam) did not have any cooperation link with Andhra during these five years.

Table 3.4 presents the data on Andhra's publication output and interstate cooperation links in different macrofields.

There are strong inter - field differences in Andhra's cooperation with other states, which can be visualized from the values of *DoI*. *Biology* has the lowest level of cooperation (5.98%), whereas *Engineering & Technology* has the highest level of cooperation (39.9%).

Research Profile

Figure 3.1 depicts the specialization profile of Andhra's research activities. Clearly visible is its strong orientation towards *Food & Agriculture* and above - average orientation towards *Chemistry*, *Biology*, *Earth & Atmospheric Science*, *Biomedical Research* and *Materials Science*. Strongly below average activities are observed in *Mathematics*, *Computer Science* and *Clinical Medicine*, and below - average activities in *Physics* and *Engineering & Technology*.

Table 3.4
Publication Output and Interstate Cooperation in Science Fields

No. of Articles	4508
No. of Interstate Cooperation Links	548
No. of International Links	473
No. of States having at least one Link	22
Domesticity Index (%)	12.16
Centrality Index	0.306
Internationalization Index (%)	10.49

Field	*No. of Articles*	*No. of Links*	*Domesticity Index (%)*
Mathematics	46	2	4.35
Physics	824	131	15.90
Chemistry	1321	88	6.67
Biology	301	18	5.98
Earth & Atmospheric Science	267	66	24.72
Food & Agriculture	263	18	6.84
Clinical Medicine	275	30	10.91
Biomedical Research	505	37	7.33
Engineering & Technology	308	83	39.90
Materials Science	201	32	15.92
Computer Science	20	3	15.00
Total	4508	548	12.16

Cooperation Profile

Figure 3.1 displays the cooperation profile of Andhra, which is more or less similar to its research profile (Pearson r = 0.76); noteworthy deviations are in *Engineering & Technology* and *Biology*. The cooperation profile indicates Andhra's strong preference for interstate cooperation in *Earth & Atmospheric Science* and above – average preference for cooperation in *Chemistry*, *Food & Agriculture*, *Engineering & Technology* and *Materials Science*.

Andhra has below – average research activity in *Engineering & Technology*, but above – average level of cooperation. On the other hand, this state has above – average activity in *Biology*, but below – average level of cooperation in this field. It appears that this state is adopting the strategy of intensification of its strengths in the fields of *Chemistry*, *Biology*, *Earth & Atmospheric Sciences*, *Biomedical Research* and *Materials Science* and rectifying its weaknesses in *Engineering & Technology* and to a limited extent in *Clinical Medicine* and *Computer Science* through interstate cooperation.

Figure 3.2 depicts bidirectional affinities of Andhra Pradesh with its eleven most significant partners. Its most important partners are Karnataka, Tamilnadu, Maharashtra and UP. The preferred fields of cooperation with these states are:

Karnataka	:	*Chemistry* (*AFI* = 41%), *Biomedical Research* (*AFI* = 25%), *Materials Science* (*AFI* = 25%)
Tamilnadu	:	*Physics* (*AFI* = 27%), *Engineering & Technology* (*AFI* = 10%)
U.P.	:	*Clinical Medicine* (*AFI* = 25%), *Engineering & Technology* (*AFI* = 24%)
Maharashtra	:	*Chemistry* (*AFI* = 18%), *Physics* (*AFI* = 14%)

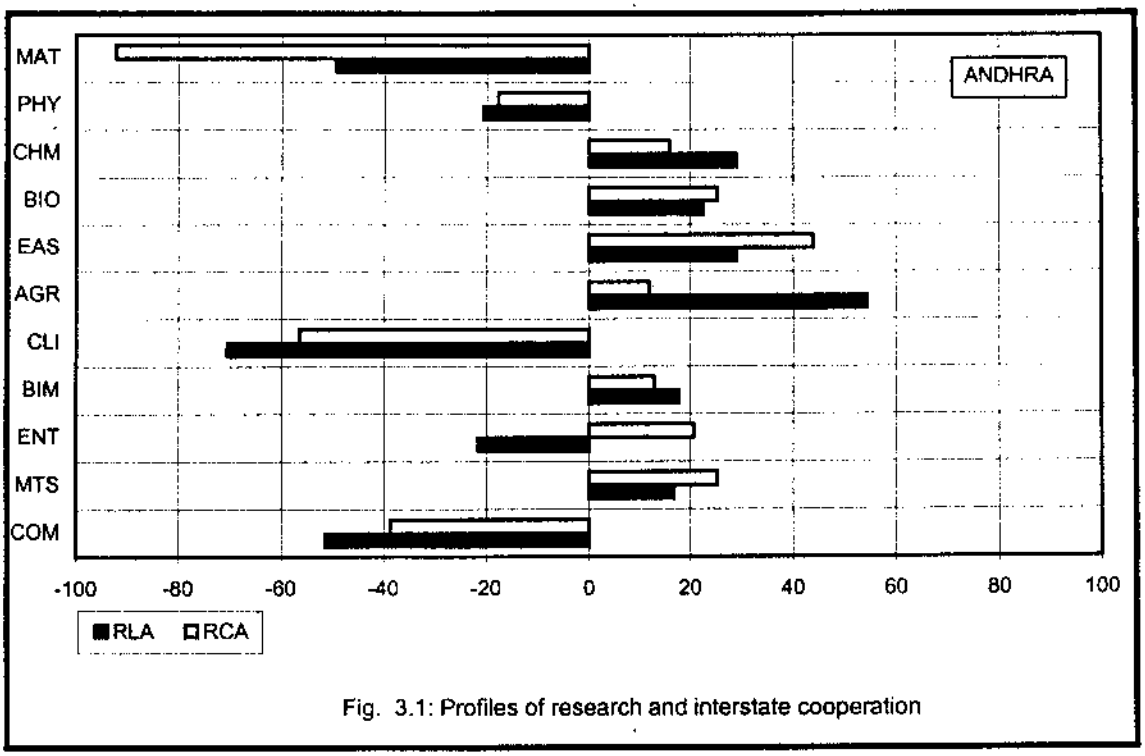

Fig. 3.1: Profiles of research and interstate cooperation

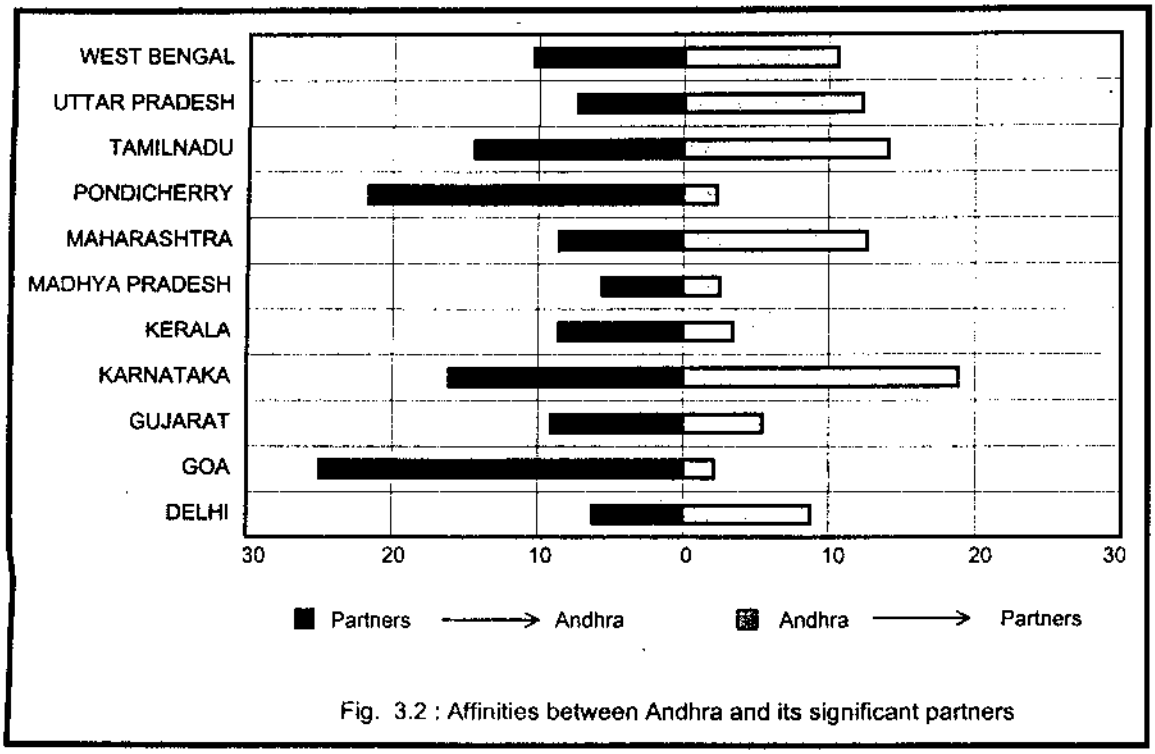

Fig. 3.2 : Affinities between Andhra and its significant partners

Assam

Assam is a small state in terms of scientific output — only 327 articles in the *SCI* – covered journals in five – years, involving 48 interstate cooperation links, spanning 14 states. This state is quite active in external cooperation in science; the values of *Domesticity Index* and *Internationalization Index* are higher than the national average, but its cooperation network is quite restricted due to its small size. As a consequence, this state lies on the periphery of the network of interstate cooperation. The eigenvector centrality index is quite low (0.025).

Table 3.5 presents the data on Assam's publication output and interstate cooperation links in different research fields.

These are strong variations in the choice of research fields for cooperation with other states. *Clinical Medicine* is the most preferred field, whereas *Food & Agriculture* is the least preferred field.

Research Profile

Figure 3.3 depicts the research specialization profile of Assam. It is characterized by strong orientation towards *Chemistry* and *Food & Agriculture.* Strong weaknesses are observed for the following fields: *Computer Science, Materials Science, Clinical Medicine, Mathematics* and (to a certain extent) *Biology* and *Engineering & Technology.*

Cooperation Profile

The cooperation profile of Assam, depicted in Figure 3.3, which indicates positive orientation towards *Mathematics, Chemistry, Biomedical Research, Earth & Atmospheric Science* and *Engineering & Technology* and negative orientation towards *Computer Science, Materials Science, Physics* and *Food & Agriculture.*

Table 3.5
Publication Output and Interstate Cooperation in Science Fields

No. of Articles	327
No. of Interstate Cooperation Links	48
No. of International Links	48
No. of States having at least one Link	14
Domesticity Index (%)	14.68
Centrality Index	0.025
Internationalization Index (%)	14.68

Field	*No. of Articles*	*No. of Links*	*Domesticity Index (%)*
Mathematics	3	1	nc
Physics	73	10	13.70
Chemistry	132	11	8.33
Biology	12	2	16.66
Earth & Atmospheric Science	14	6	42.86
Food & Agriculture	17	1	5.86
Clinical Medicine	11	5	45.45
Biomedical Research	31	4	12.90
Engineering & Technology	20	7	35.00
Materials Science	4	1	nc
Computer Science	0	0	na
Total	327	48	14.68

Figure 3.4 depicts bidirectional affinities of Assam with its seven most significant partners. Three most important partners of this state are: UP, Maharashtra and West Bengal. Together they account for more than 50% of Assam's interstate cooperation links.

West Bengal : *Physics* (*AFI* = 30%)

Maharashtra : *Chemistry* (*AFI* = 27%)

U.P. : *Engineering & Technology* (*AFI* = 43%), *Earth & Atmospheric Science* (*AFI* = 33%)

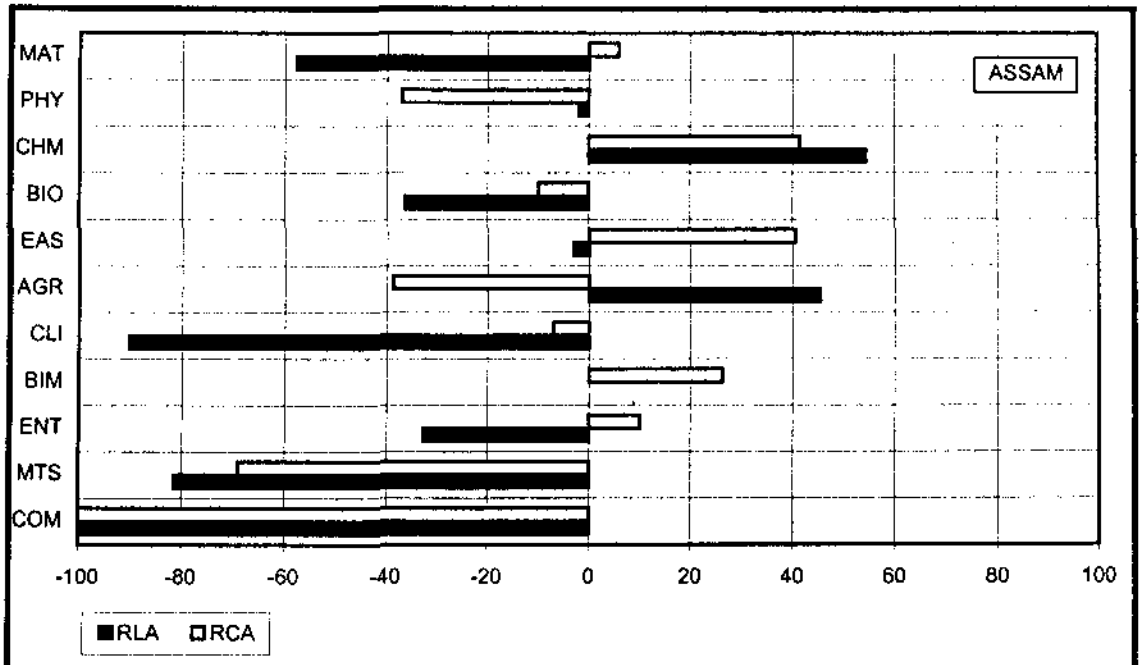

Fig. 3.3: Profiles of research and interstate cooperation

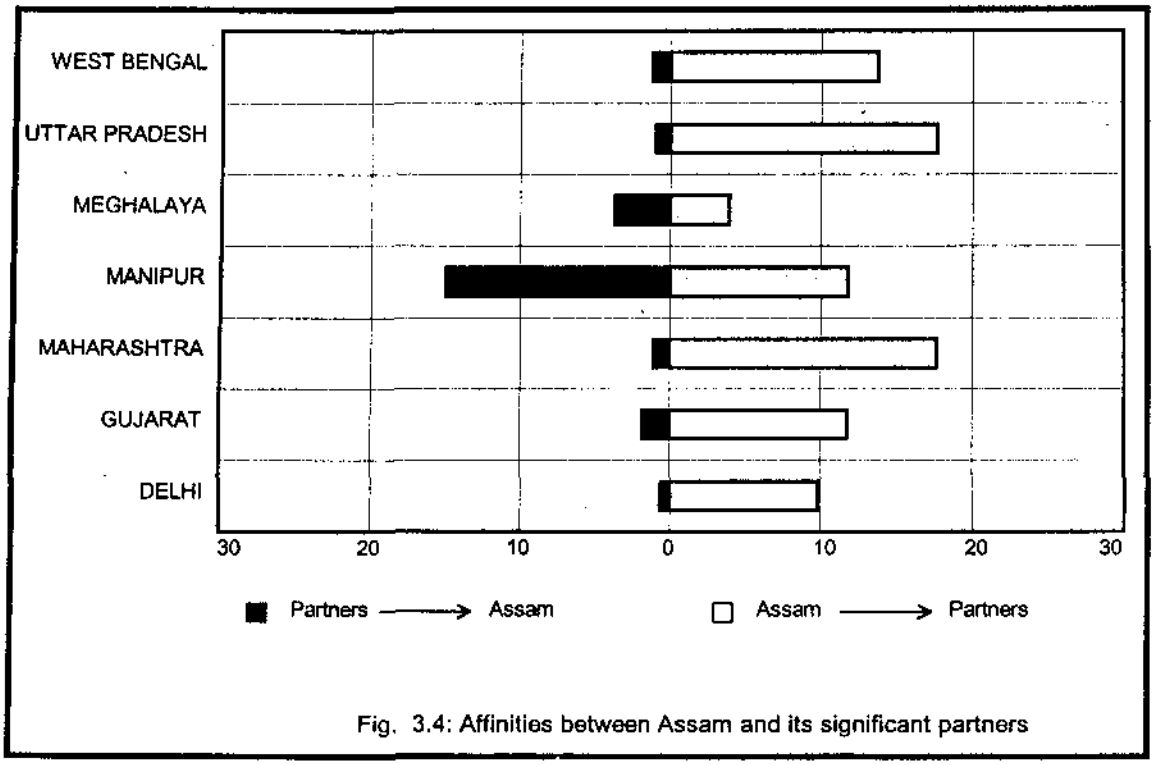

Fig. 3.4: Affinities between Assam and its significant partners

Bihar

Bihar is relatively a (scientifically) small state. It contributed only 648 articles to the mainstream journals covered by the *Science Citation Index* during the five – year period 1990 – 1994. But it is quite active in developing cooperation links, both within and outside the country, which may be visualized from the high values of *Domesticity Index* (28.9%) and *Internationalization Index* (26.1%). Its span of cooperation is limited to 17 states.

Table 3.6 presents the data on publication output and interstate cooperation links in different research fields.

There are strong differences among the fields in interstate cooperation. The values of *Domesticity Index* vary from a low of 9.7% for *Food & Agriculture* to a high of 44.2% for *Materials Science*.

Research Profile

Figure 3.5 shows the specialization profile of Bihar. Strengths are identified for *Food & Agriculture*, *Earth & Atmospheric Science* and high strengths for *Engineering & Technology*, *Materials Science* and *Computer Science*. Weaknesses are identified for *Physics*, *Clinical Medicine*, *Biomedical Research* and strong weaknesses for *Mathematics* and *Chemistry*.

Cooperation Profile

Figure 3.5 depicts the cooperation profile of Bihar, which indicates its strong preference for cooperation with other states in *Engineering & Technology* and *Materials Science*. It has also above – average level of cooperation in *Mathematics* and *Earth & Atmospheric Science*.

There are important differences between the specialization and cooperation profiles. Research activity in *Mathematics* is quite below – average, but the level of cooperation with other states is above – average. Research activity in *Food & Agriculture* is above average, but cooperation activity is below average. Research activity in *Computer Science* is much above – average but cooperation in this field is below – average.

Figure 3.6 depicts bidirectional affinities of Bihar with its nine most significant partners. UP and West Bengal are the most important partners of this state, each of these accounts for about 30% of Bihar's interstate cooperation links. The most preferred fields for cooperation with these states are:

U.P. : *Engineering & Technology* (*AFI* = 42%), *Biology* (*AFI* = 62%)
West Bengal : *Physics* (*AFI* = 43%), *Engineering & Technology* (*AFI* = 28%)

Table 3.6
Publication Output and Interstate Cooperation in Science Fields

No. of Articles	648
No. of Interstate Cooperation Links	187
No. of International Links	169
No. of States having at least one Link	17
Domesticity Index (%)	28.86
Centrality Index	0.111
Internationalization Index (%)	26.08

Field	*No. of Articles*	*No. of Links*	*Domesticity Index (%)*
Mathematics	5	4	80.00
Physics	111	28	25.22
Chemistry	60	14	23.33
Biology	34	8	23.53
Earth & Atmospheric Science	52	16	30.77
Food & Agriculture	31	3	9.68
Clinical Medicine	57	10	17.54
Biomedical Research	43	4	9.30
Engineering & Technology	170	67	39.41
Materials Science	52	23	44.23
Computer Science	10	1	10.00
Total	648	187	28.86

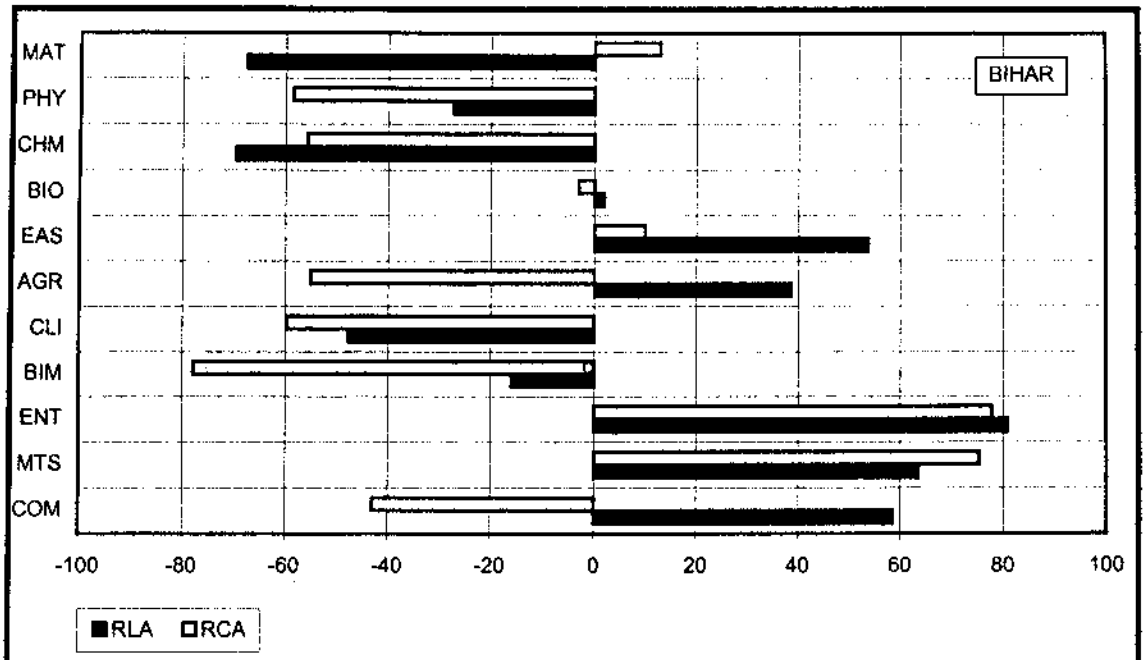

Fig. 3.5: Profiles of research and interstate cooperation

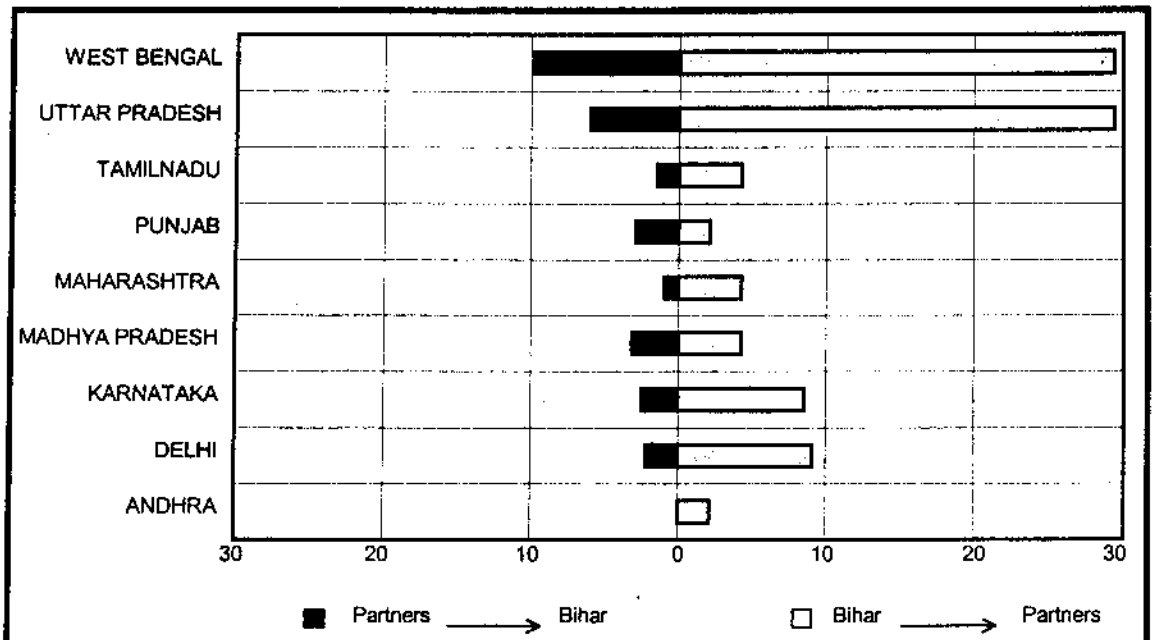

Fig. 3.6 : Affinities between Bihar and its significant partners

Chandigarh

In terms of geographical area and population, the Union Territory of Chandigarh is small, but in terms of research output, its 'weight' is more than twice that of Bihar. Chandigarh contributed 1441 articles to the *SCI* – covered journals (Bihar contributed only 648 articles), involving 165 interstate cooperation links and 152 international cooperation links.

Table 3.7 presents the data on publication output and interstate cooperation links of Chandigarh. Inter – field variations in cooperation links may be visualized from the values of *Domesticity Index*, which vary from a low of 4.5% for *Mathematics* to a high of 57% for *Earth & Atmospheric Science*.

Research Profile

Figure 3.7 displays the specialization profile of Chandigarh. Clearly visible is the dominating orientation towards *Clinical Medicine* and *Biomedical Research*. Below – average activity is observed in *Mathematics* and strongly below – average activities are observed in the remaining fields.

Cooperation Profile

The cooperation profile of Chandigarh (Figure 3.7) shows strong preference for cooperation in *Clinical Medicine* and *Biomedical Research*.

When we compare the values of *RLA* and *RCA*, it appears that Chandigarh is adopting the policy of rectification of its weaknesses in several areas through interstate cooperation: *Physics*, *Chemistry*, *Earth & Atmospheric Science* and *Food & Agriculture*.

Chandigarh has cooperation links with 16 states. Figure 3.8 depicts bidirectional affinities of Chandigarh with its ten significant partner states. Its most important partners are: Delhi, Punjab and Maharashtra. The preferred fields for cooperation with these states are:

Delhi	:	Cli*nical Medicine* (*AFI* = 31.8%), *Biomedical Research* (*AFI* = 23.5%), *Engineering & Technology* (*AFI* = 37.5%), *Physics* (*AFI* = 16.7%)
Punjab	:	*Physics* (*AFI* = 14.6%), *Clinical Medicine* (*AFI* = 11.4%)
Maharashtra	:	*Physics* (*AFI* = 18.8%), *Chemistry* ((*AFI* = *31.4%)* = *31.4%)* = 23.6%), *Clinical Medicine* (*AFI* = 15.9%)

Table 3.7
Publication Output and Interstate Cooperation in Science Fields

No. of Articles	1441
No. of Interstate Cooperation Links	165
No. of International Links	152
No. of States having at least one Link	16
Domesticity Index (%)	11.45
Centrality Index	0.076
Internationalization Index (%)	10.55

Field	*No. of Articles*	*No. of Links*	*Domesticity Index (%)*
Mathematics	22	11	4.54
Physics	175	48	27.43
Chemistry	174	17	9.77
Biology	24	2	8.33
Earth & Atmospheric Science	14	8	57.14
Food & Agriculture	8	4	50.00
Clinical Medicine	708	44	6.21
Biomedical Research	229	17	7.42
Engineering & Technology	20	6	30.00
Materials Science	6	3	50.00
Computer Science	1	0	nc
Total	1441	165	11.45

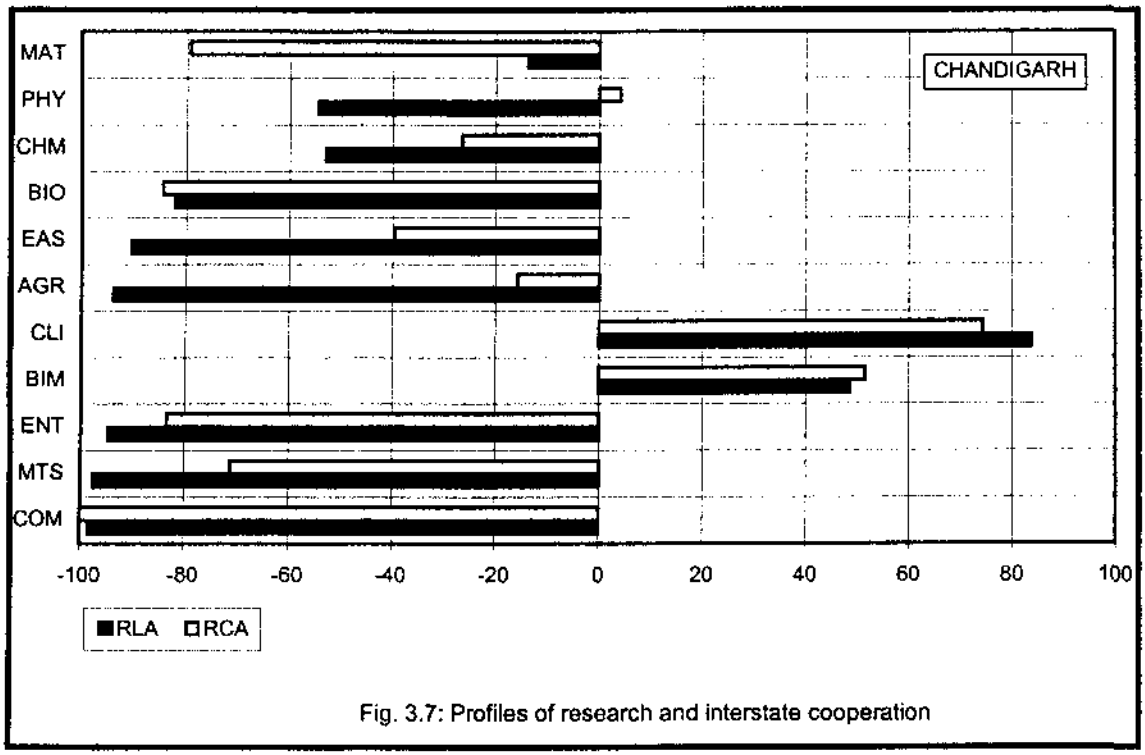

Fig. 3.7: Profiles of research and interstate cooperation

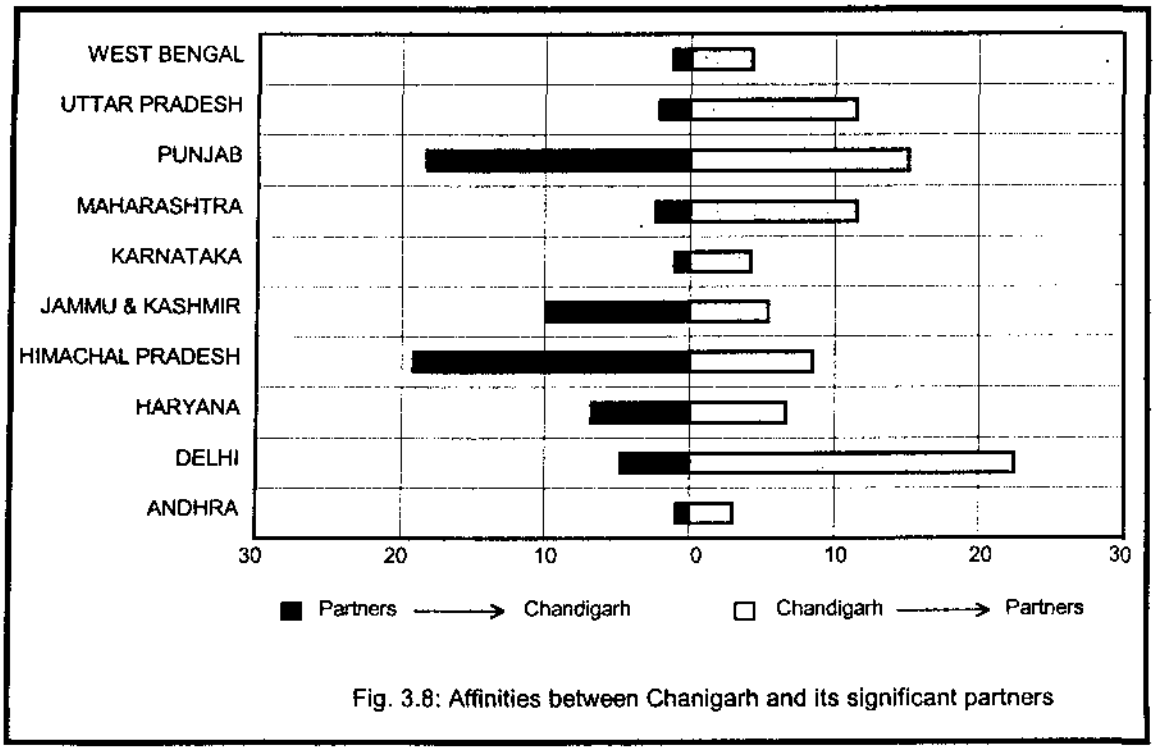

Fig. 3.8: Affinities between Chanigarh and its significant partners

Delhi

Delhi occupies an important position in the scientific map of India, both in terms of publication output and interstate and international cooperation. During the five-year period: 1990-1994, this state contributed 5,937 articles, constituting about 11.1% of India's total publication output. Its involvement in interstate and international cooperation may be visualized from the values of *Domesticity Index* (12.1%) and *Internationalization Index* (11.7%).

Table 3.8 presents the data on Delhi's publication output and interstate cooperation links. This state had 718 cooperation links, spanning 23 states. Only four states (Andaman, Tripura, Mizoram and Sikkam) did not have any cooperation link with Delhi.

There are strong inter – field variations in Delhi's cooperation with other states. The value of *Domesticity Index* varies from a low of 8.2% for *Clinical Medicine* to a high of 28.2% for *Food & Agriculture*.

Research Profile

Figure 3.9 shows the calculated specialization profile of Delhi. Above average values of the specialization index are observed for *Mathematics*, *Clinical Medicine* and *Biomedical Research*; below-average values are observed for *Chemistry*, *Earth & Atmospheric Science*, *Food & Agriculture* and *Materials Science;* near average values are observed for *Physics*, *Biology* and *Computer Science*.

Cooperation Profile

The cooperation profile depicted in Figure 3.9 indicates Delhi's strong preference for cooperation in *Mathematics*, *Clinical Medicine*, *Biomedical Research* and *Computer*

Science; near average orientation for cooperation in *Biology*, *Earth & Atmospheric Science* and *Food & Agriculture*; below-average orientation for cooperation in *Physics*, *Chemistry* and *Engineering & Technology*.

Figure 3.10 shows bidirectional affinities of Delhi with its 11 significant partners. Its three most important partners are UP, Maharashtra and Karnataka. Its cooperation with UP focusses on *Engineering & Technology* (*AFI* = 39.4), *Clinical Medicine* (*AFI* = 31.4%), *Chemistry* (*AFI* = 29.7%), *Physics* (*AFI* = 28.1%) and *Biology* (*AFI* = 25.0%). Its cooperation with Maharshtra and Karnataka is rather diffused and there is no prominent field of cooperation.

Table 3.8
Publication Output and Interstate Cooperation in Science Fields

No. of Articles	5937
No. of Interstate Cooperation Links	728
No. of International Links	693
No. of States having at least one Link	23
Domesticity Index (%)	12.26
Centrality Index	0.391
Internationalization Index (%)	11.67

Field	*No. of Articles*	*No. of Links*	*Domesticity Index (%)*
Mathematics	158	19	12.02
Physics	1158	185	15.98
Chemistry	705	74	10.50
Biology	306	36	11.76
Earth & Atmospheric Science	202	57	28.22
Food & Agriculture	110	26	23.64
Clinical Medicine	1677	137	8.17
Biomedical Research	681	66	9.69
Engineering & Technology	424	79	18.63
Materials Science	184	36	19.57
Computer Science	52	13	25.00
Total	5937	728	12.26

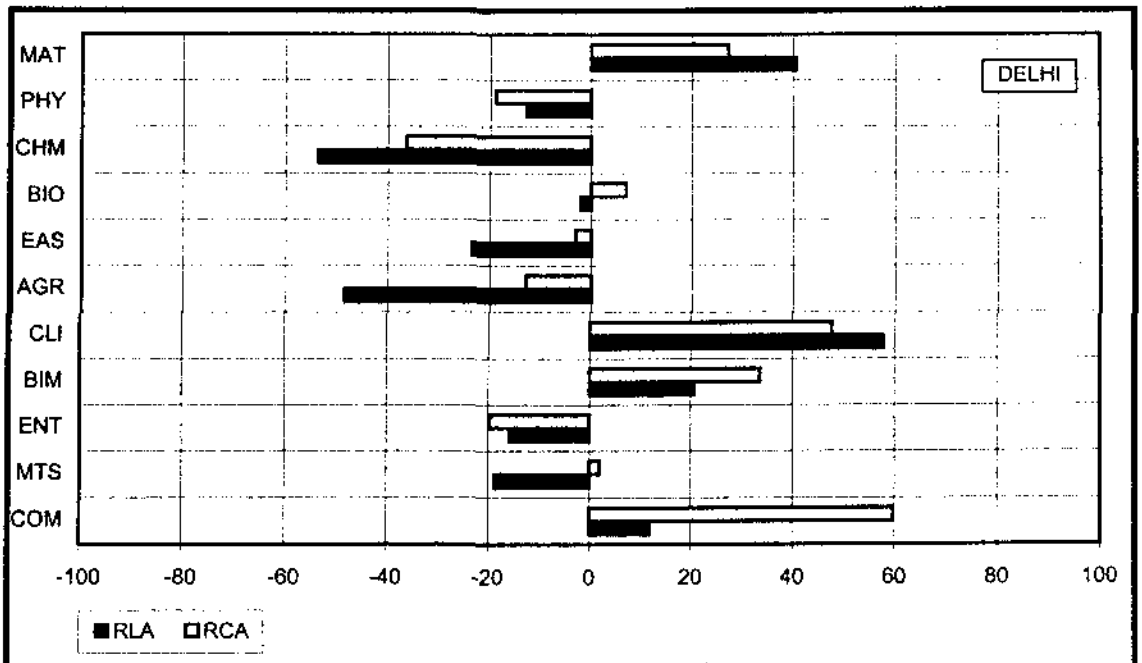

Fig. 3.9: Profiles of research and interstate cooperation

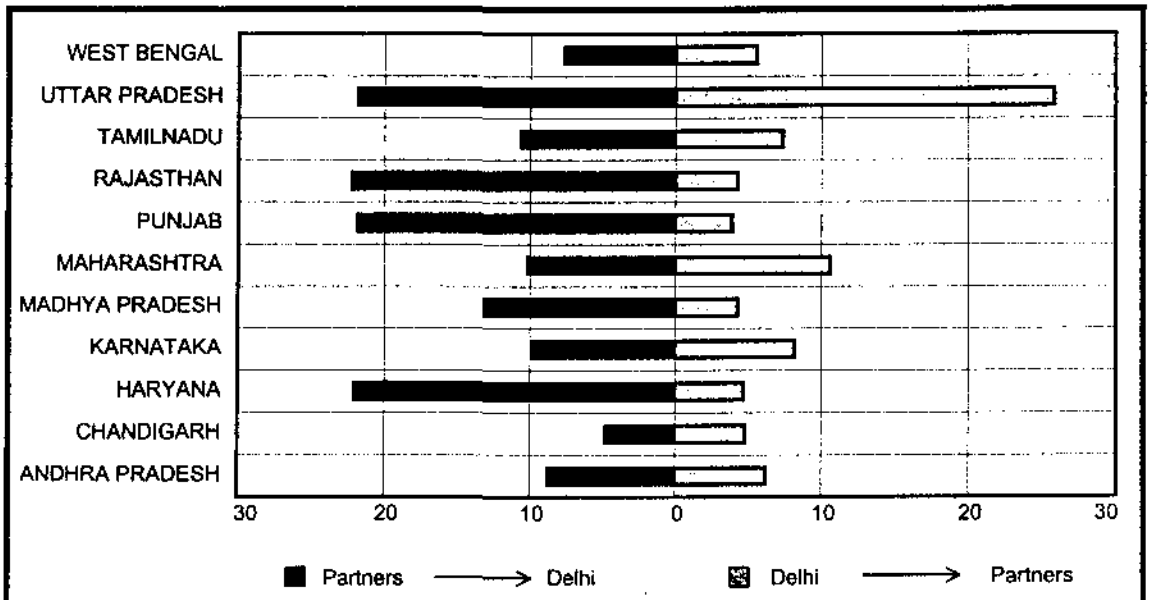

Fig. 3.10: Affinities between Delhi and its significant partners

Goa

Goa is a small state in terms of scientific output and cooperation links. This state contributed 307 articles in the *SCI*-covered journals in five-years (1990-1994), which involved 73 interstate cooperation links, spanning eight states. This state is quite active in developing cooperation links, both within and outside the country, which may be visualized from the high values of *Domesticity Index* (23.8%) and *Internationalization Index* (29.6%).

Table 3.9 presents the data on publication output and interstate cooperation links in different fields.

Strong inter – field differences are observed in Goa's cooperation with other states. The value of *Domesticity Index* varies from a low of 12.4% for *Biology* to a high of 60.0% for *Physics*.

Research Profile

The specialization profile of this state is shown in Figure 3.11. Clearly visible is the dominating orientation towards *Biology* and *Earth & Atmospheric Science*. Research activity in *Mathematics* is below-average; and in other fields, strongly below-average.

Cooperation Profile

Figure 3.11 depicts the cooperation profile of Goa, which is quite similar to its research profile. *Biology* and *Earth & Atmospheric Sciences* are fields of strong preference for interstate cooperation. Research activity in *Mathematics* is very small, but has a tendency towards cooperation with other states.

Figure 3.12 shows bidirectional affinities of Goa with its significant partners. Its three most important partners are Maharashtra, Andhra and UP. These states together account for about 75% of Goa's interstate links.

Cooperation with UP and Andhra emphasizes *Earth & Atmospheric Science* (Affinity with Andhra: 50%; Affinity with UP: 21%). Cooperation with Maharashtra strongly emphasizes *Physics* (*AFI* = 78%).

Table 3.9
Publication Output and Interstate Cooperation in Science Fields

No. of Articles	307
No. of Interstate Cooperation Links	73
No. of International Links	63
No. of States having at least one Link	11
Domesticity Index (%)	23.78
Centrality Index	0.029
Internationalization Index (%)	29.58

Field	*No. of Articles*	*No. of Links*	*Domesticity Index (%)*
Mathematics	4	1	nc
Physics	15	9	60.00
Chemistry	17	3	17.65
Biology	50	6	12.00
Earth & Atmospheric Science	168	24	14.29
Food & Agriculture	3	0	nc
Clinical Medicine	10	0	0
Biomedical Research	1	2	18.18
Engineering & Technology	14	3	21.43
Materials Science	0	0	na
Computer Science	0	0	na
Total	307	73	23.78

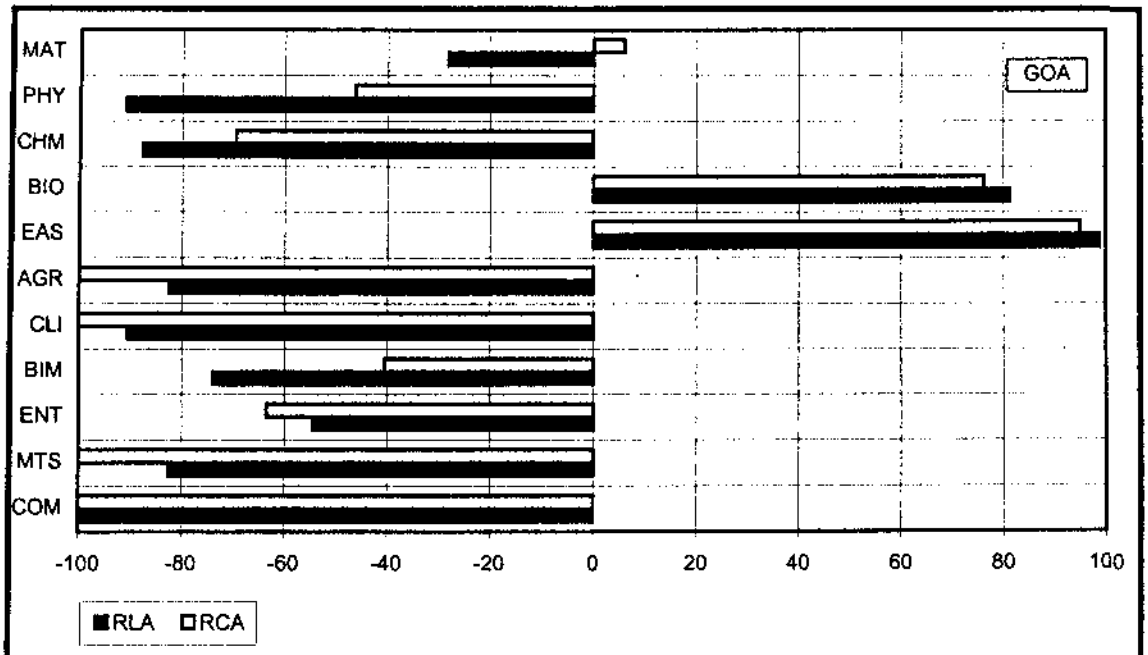

Fig. 3.11: Profiles of research and interstate cooperation

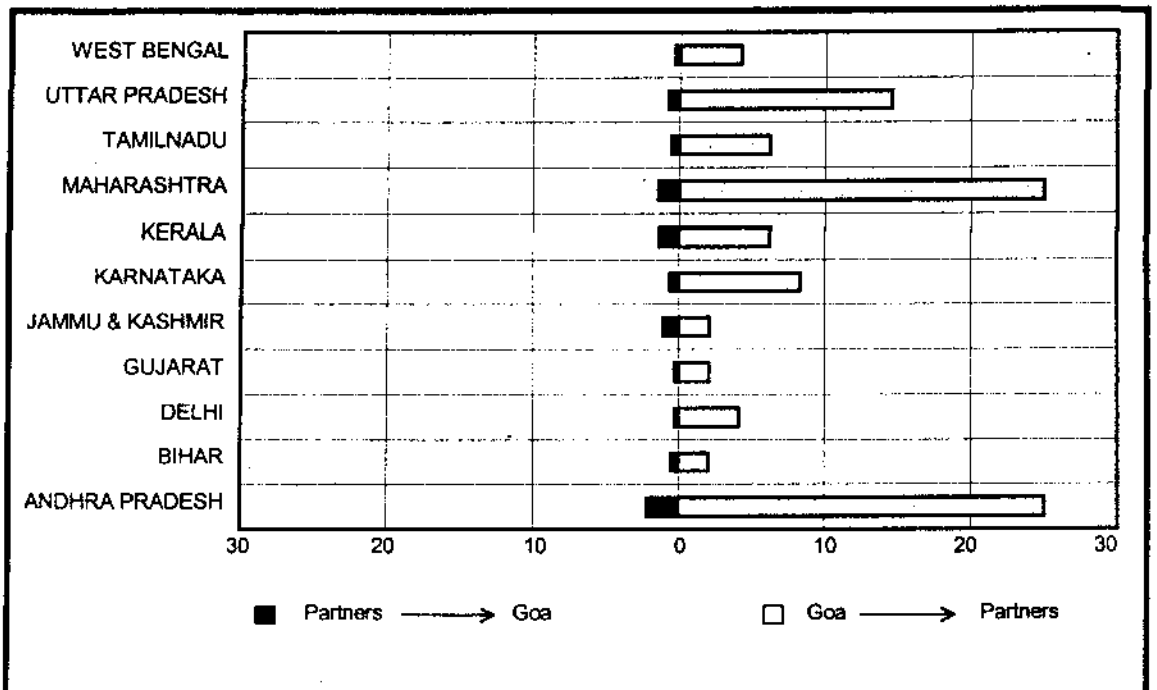

Fig. 3.12: Affinities between Goa and its significant partners

Gujarat

The state of Gujarat contributed 1732 articles in the *SCI*-covered journals, involving 323 interstate cooperation links and 208 international cooperation links.

This state has cooperation links with 19 states; its status in the interstate network of scientific cooperation may be visualized from the values of *Bonacich Eigenvector Centrality Index* (0.187), which is neither high nor low.

Table 3.10 presents the data on publication output and interstate cooperation links in different fields.

Evidently all the fields do not attract the same level of cooperation. The values of *Domesticity Index* vary from a low of 5.9% for *Mathematics* to a high of 41.2% for *Food & Agriculture.*

Research Profile

The specialization profile of Gujarat is depicted in Figure 3.13. Clearly visible is the dominating orientation towards *Earth & Atmospheric Science. Physics* and *Chemistry* show above-average level of research activity. Strongly below-average research activities are observed for the remaining fields, particularly *Engineering & Technology, Computer Science* and *Mathematics.*

Cooperation Profile

The cooperation profile of Gujarat (Fig. 3.13) is similar to its research profile; the only deviation is in *Food & Agriculture.* Research activity in this area is below the national average, but cooperation level is above the national average. Cooperation activity in

Physics is slightly below-average, whereas research activity in this area is slightly above-average.

Figure 3.14 shows bidirectional affinities of Gujarat with its eleven important partners. Maharashtra is the most important partner of Gujarat, followed by West Bengal and UP. These three states account for more than 50% of all interstate cooperation links of Gujarat.

The preferred fields of cooperation with these states are:

Maharashtra : *Physics* (*AFI* = 38.5%), *Clinical Medicine* (*AFI* = 31.2%), *Earth & Atmospheric Science* (*AFI* = 25.4%)

West Bengal : *Chemistry* (*AFI* = 21.7%), *Earth & Atmospheric Science* (*AFI* = 10.2%), *Physics* (*AFI* = 9.2%)

UP : *Earth & Atmospheric Science* (*AFI* = 15.2%), *Chemistry* (*AFI* = 11.6%), *Clinical Medicine* (*AFI* = 12.5%)

Table 3.10
Publication Output and Interstate Cooperation in Science Fields

No. of Articles	1732
No. of Interstate Cooperation Links	323
No. of International Links	208
No. of States having at least one Link	19
Domesticity Index (%)	18.65
Centrality Index	0.187
Internationalization Index (%)	12.01

Field	*No. of Articles*	*No. of Links*	*Domesticity Index (%)*
Mathematics	17	1	5.88
Physics	422	91	21.56
Chemistry	541	60	11.09
Biology	49	12	24.49
Earth & Atmospheric Science	205	59	28.78
Food & Agriculture	34	14	41.17
Clinical Medicine	185	32	17.30
Biomedical Research	103	11	10.68
Engineering & Technology	55	12	21.82
Materials Science	38	3	7.89
Computer Science	3	1	nc
Total	1732	323	18.65

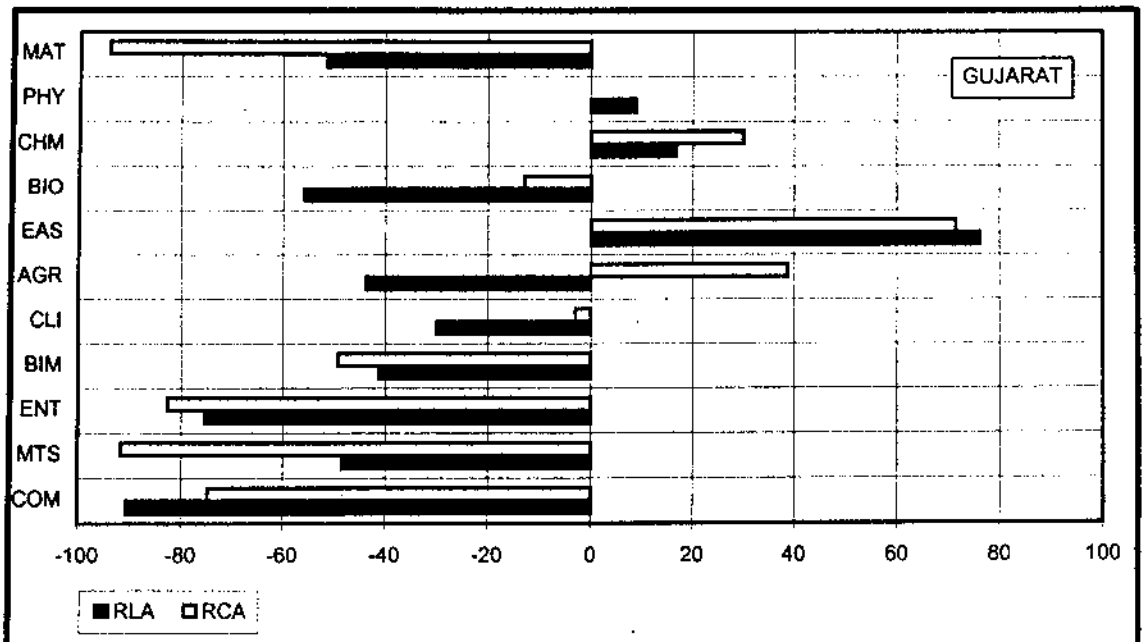

Fig. 3.13 : Profiles of research and interstate cooperation

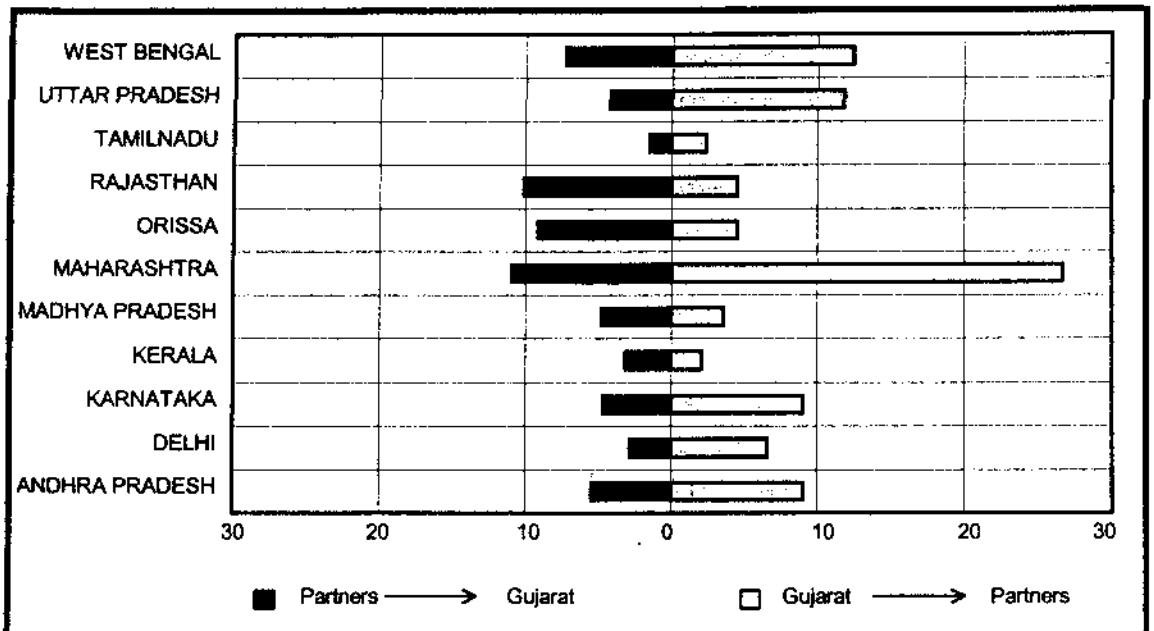

Fig. 3.14: Affinities between Gujarat and its significant partners

Haryana

Haryana had published 1060 articles in the *SCI*-covered journals, involving 163 interstate and 151 international cooperation links. This state occupies a near-peripheral position in the network of interstate cooperation; the value of *Bonacich Eigenvector Centrality Index* is low (0.080). Haryana had cooperation links with 17 states.

Table 3.11 presents the data on publication output and cooperation links of Haryana in different fields.

There are strong inter – field variations in the degree of cooperation with other states in the country. *Physics* attracts the highest level of cooperation (*Domesticity Index* = 46.0), whereas *Food & Agriculture* attracts the lowest level of cooperation (*Domesticity Index* = 8.48).

Research Profile

Figure 3.15 depicts the specialization profile of Haryana, which is characterized by strong orientation of its research activity towards *Food & Agriculture* and *Biology*; below – average research activity in *Computer Science*, *Mathematics* and *Physics* and about average activity in the remaining fields (viz. *Chemistry*, *Earth & Atmospheric Sciences*, *Clinical Medicine*, *Biomedical Research* and *Engineering & Technology*).

Cooperation Profile

The cooperation profile of this state (Fig. 3.15) shows remarkable similarity to its research profile. This state has strong preference for cooperation in *Food & Agriculture*, *Biology* and *Mathematics*. This state does not attract much cooperation in *Computer Science* and *Materials Science*.

Figure 3.16 shows bidirectional affinities of Haryana with its eleven significant partners. Its most important partners are UP and Delhi. Together, these two states account for more than 50% of intra-country cooperation links of this state. The most preferred fields for cooperation with these states are:

UP : *Engineering & Technology* (*AFI* = 47.6%), *Physics* (*AFI* = 36.9%), *Clinical Medicine* (*AFI* = 23.5%), *Chemistry* (*AFI* = 31.4%)

Delhi : *Biomedical Research* (*AFI* = 50%), *Earth & Atmospheric Science* (*AFI* = 33.0%), *Physics* (*AFI* = 26.1%)

Table 3.11
Publication Output and Interstate Cooperation in Science Fields

No. of Articles	1060
No. of Interstate Cooperation Links	163
No. of International Links	151
No. of States having at least one Link	17
Domesticity Index (%)	15.38
Centrality Index	0.080
Internationalization Index (%)	14.25

Field	*No. of Articles*	*No. of Links*	*Domesticity Index (%)*
Mathematics	2	0	0
Physics	100	46	46.00
Chemistry	301	24	7.97
Biology	121	11	9.09
Earth & Atmospheric Science	40	12	30.00
Food & Agriculture	165	14	8.48
Clinical Medicine	131	17	12.98
Biomedical Research	81	10	12.34
Engineering & Technology	78	21	26.92
Materials Science	10	4	40.00
Computer Science	5	1	20.00
Total	1060	160	15.38

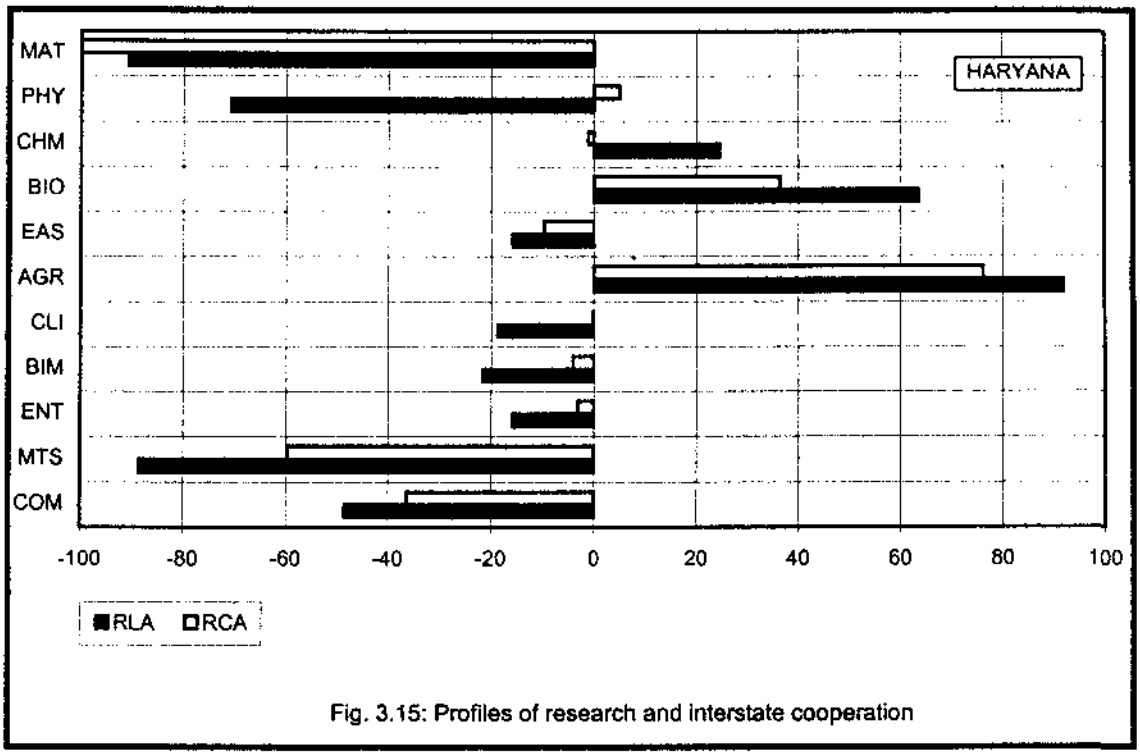

Fig. 3.15: Profiles of research and interstate cooperation

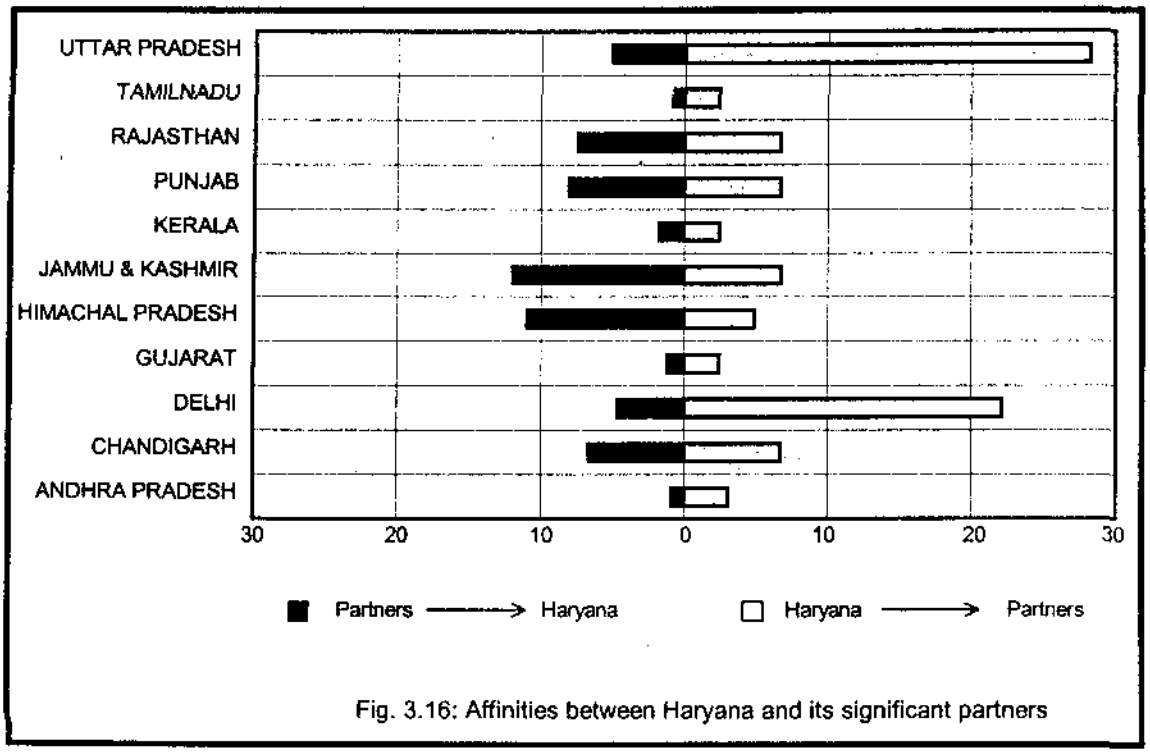

Fig. 3.16: Affinities between Haryana and its significant partners

Himachal Pradesh

Himachal Pradesh contributed 324 articles in the *SCI*-covered journals during the five-year period: 1990-1994, involving 54 interstate cooperation links and 42 international cooperation links. This state had links with 15 states, but due to its small (scientific) size, it resides in the periphery of the interstate cooperation network. The value of *Bonacich Eigenvector Centrality Index* is only 0.029.

Table 3.12 presents the data on Himachal's publication output and interstate cooperation links. There are wide inter-field variations in cooperation links, ranging from 0% for *Mathematics* to 34.5% for *Biomedical Research.*

Research Profile

Figure 3.17 depicts the specialization profile of this state, which is characterized by strong orientation towards *Biology* and *Food & Agriculture* and positive orientation towards *Mathematics.* Strong weaknesses are observed for the following fields: *Earth & Atmospheric Science, Engineering & Technology, Materials Science* and *Computer Science.* About-average activities in *Clinical Medicine* and *Biomedical Research* and below-average activities in *Physics* and *Chemistry* are also observed.

Cooperation Profile

Figure 3.17 depicts the cooperation profile of this state, which indicates its strong preference for cooperation in *Biology, Food & Agriculture, Clinical Medicine* and *Biomedical Research.* It has below average level of cooperation in the remaining fields.

There are important differences between the specialization and cooperation profiles. Research activities in *Clinical Medicine* and *Biomedical Research* are about the average, but the level of interstate cooperation in these two fields is well above the average.

Figure 3.18 depicts bidirectional affinities of Himachal Pradesh with its significant partners states. Its three most important partners are: Chandigarh, Delhi and UP, which together account for about 50% of Himachal's interstate cooperation links.

The most preferred fields for cooperation with these states are:

Chandigarh	:	*Physics* (*AFI* = 50%), *Earth & Atmospheric Science* (2 out of 3 cooperation links), *Clinical Medicine* (*AFI* = 30.8%)
Delhi	:	*Biomedical Research* (*AFI* = 30%)
UP	:	*Biology* (*AFI* = 30%), *Biomedical Research* (*AFI* = 30%).

Table 3.12
Publication Output and Interstate Cooperation in Science Fields

No. of Articles	324
No. of Interstate Cooperation Links	59
No. of International Links	42
No. of States having at least one Link	15
Domesticity Index (%)	18.21
Centrality Index	0.029
Internationalization Index (%)	12.96

Field	*No. of Articles*	*No. of Links*	*Domesticity Index (%)*
Mathematics	8	0	0
Physics	49	8	16.32
Chemistry	52	3	5.77
Biology	57	10	17.54
Earth & Atmospheric Science	4	3	nc
Food & Agriculture	45	8	17.78
Clinical Medicine	43	13	30.23
Biomedical Research	29	10	34.48
Engineering & Technology	5	2	40.00
Materials Science	3	2	nc
Computer Science	0	0	na
Total	295	59	16.67

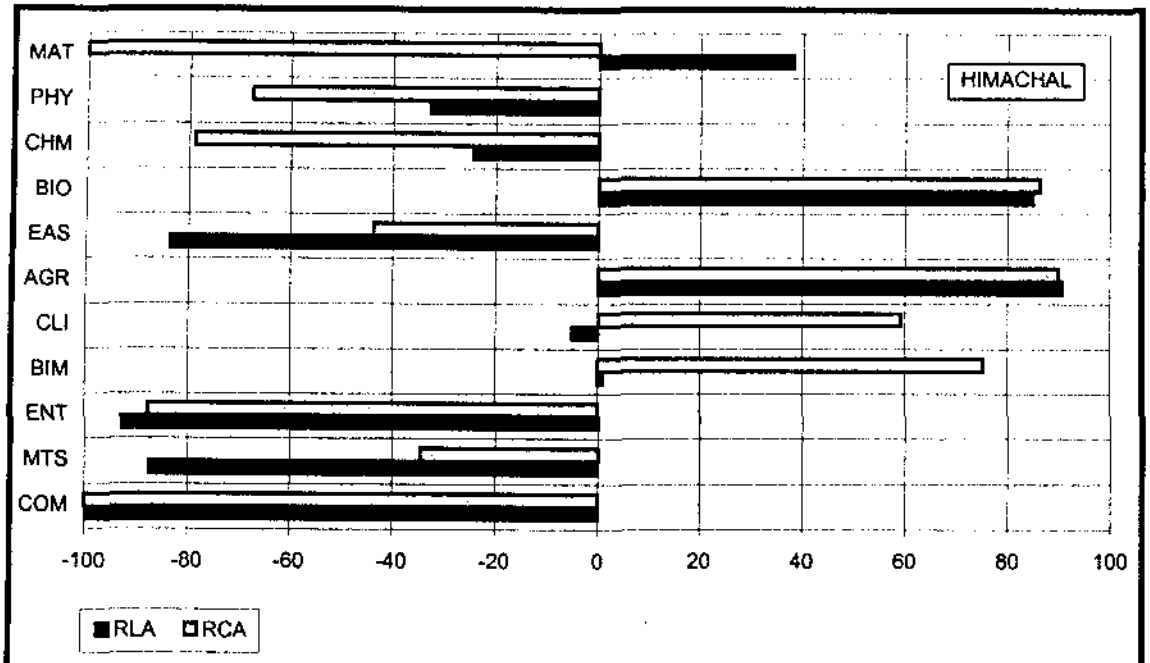

Fig. 3.17: Profiles of research and interstate cooperation

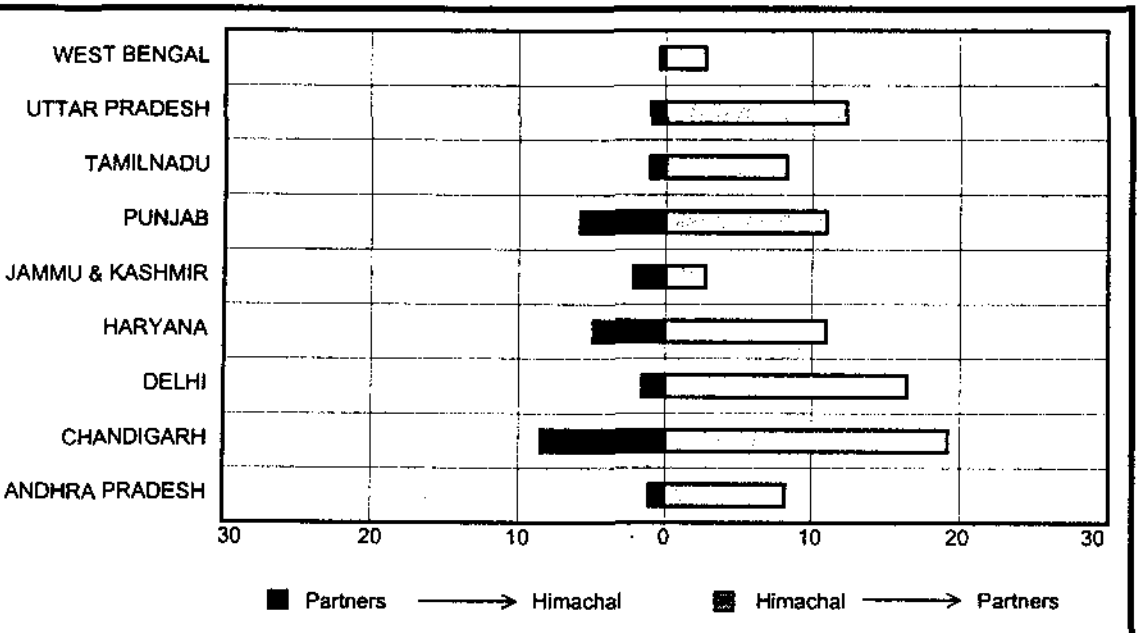

Fig. 3.18: Affinities between Himachal and its significant partners

Jammu & Kashmir

The state of Jammu & Kashmir had published 376 articles in the *SCI*-covered journals during the five-year period 1990-1994. This state is quite active in developing scientific cooperation, both within and outside the country, which could be visualized from the high values of *Domesticity Index* (24.5) and *Internationalization Index* (22.9).

Table 3.13 presents the data on publication output and interstate cooperation links. There are strong inter-field differences in J&K's cooperation with other states. The values of *Domesticity Index* vary from a low of 8.33% for *Food & Agriculture* and *Materials Science* each to a high of 47.8% for *Physics*.

Research Profile

Figure 3.19 reveals the specialization profile of J&K, which is characterized by strong orientation towards *Biology*, *Clinical Medicine*, *Biomedical Research* and *Earth & Atmospheric Science*, about average orientation towards *Food & Agriculture* and *Materials Science* and strong negative orientation towards the remaining fields.

Cooperation Profile

The cooperation profile of this state is quite similar to its specialization profile. The state has strong preference for cooperation in *Biology*, *Clinical Medicine*, *Biomedical Research* and *Earth & Atmospheric Science*.

Figure 3.20 shows bidirectional affinities of J&K towards its thirteen significant partner states. UP, Haryana and Delhi are its three most important partners. The dominating fields of cooperation with these states are:

UP : *Biology* (*AFI* = 53.8%), *Earth & Atmospheric Science* (*AFI* =

62.5%)

Haryana : *Chemistry* (*AFI* = 70%)

Delhi : No specific field dominates J&K's cooperation with Delhi.

Table 3.13
Publication Output and Interstate Cooperation in Science Fields

No. of Articles	376
No. of Interstate Cooperation Links	92
No. of International Links	86
No. of States having at least one Link	19
Domesticity Index (%)	24.47
Centrality Index	0.040
Internationalization Index (%)	22.87

Field	*No. of Articles*	*No. of Links*	*Domesticity Index (%)*
Mathematics	4	1	nc
Physics	46	27	47.82
Chemistry	55	10	18.18
Biology	49	13	26.53
Earth & Atmospheric Science	24	8	33.33
Food & Agriculture	12	1	8.33
Clinical Medicine	100	13	13.00
Biomedical Research	41	13	31.71
Engineering & Technology	2	0	nc
Materials Science	12	1	8.33
Computer Science	0	0	na
Total	376	92	24.47

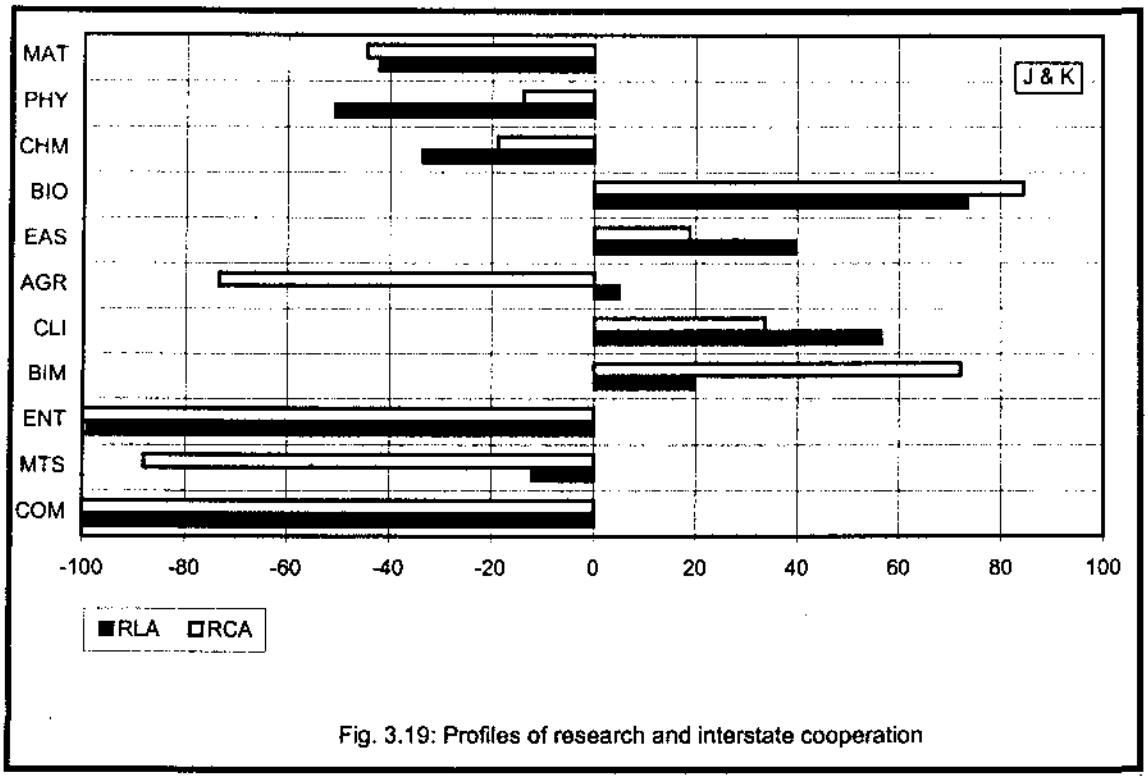

Fig. 3.19: Profiles of research and interstate cooperation

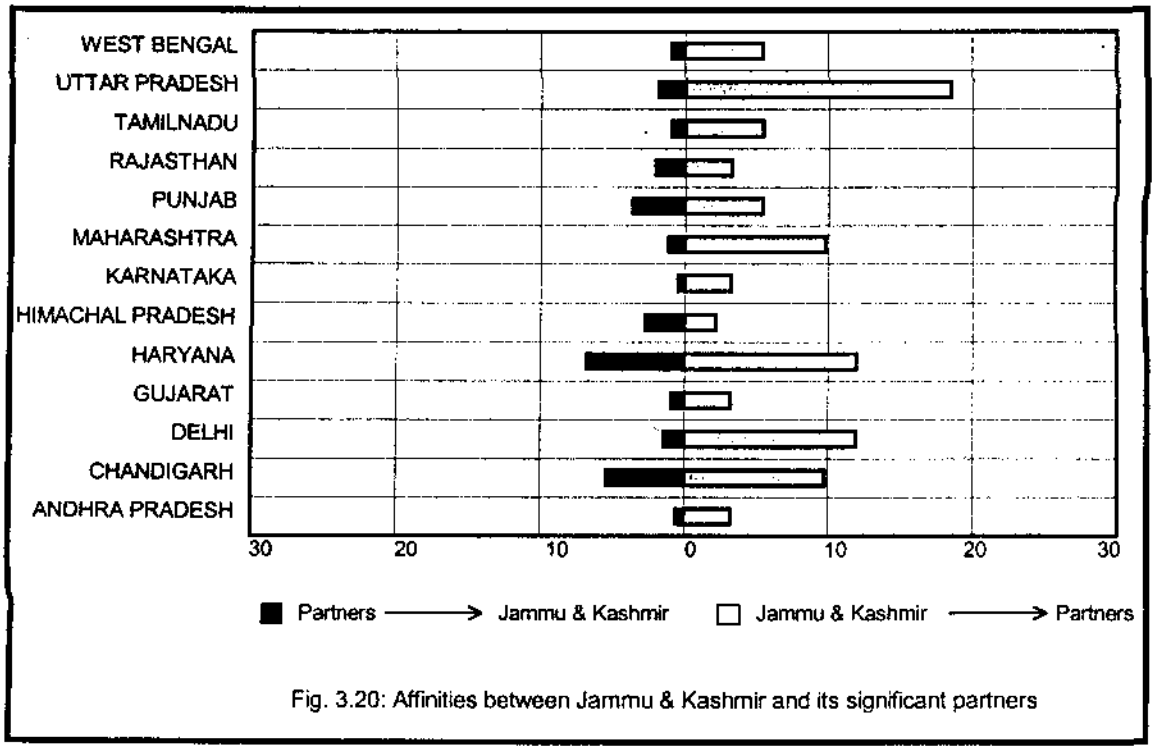

Fig. 3.20: Affinities between Jammu & Kashmir and its significant partners

Karnataka

Karnataka occupies an important position in the scientific map of India. During the five-year period: 1990-1994, this state contributed 5,378 articles to the *SCI*-covered journals, constituting about 9.0% of India's total publication output. This state is quite active in interstate (*Domesticity Index* = 10.84%) and international cooperation (*Internationalization Index* = 10.7%). This state had published more articles than Andhra, had more international links, but less interstate links than Andhra. It had cooperation links with 20 states, whereas Andhra had links with 22 states.

Table 3.14 presents the data on Karnataka's publication output and interstate cooperation links in different fields.

There are strong inter-field variations in Karnataka's cooperation with other states; the values of *Domesticity Index* vary from a low of 4.2% for *Food & Agriculture* to a high of 38.7% for *Earth & Atmospheric Science*.

Research Profile

Figure 3.21 depicts the specialization profile of Karnataka's research activities. Strengths are observed for the following fields: *Mathematics*, *Physics*, *Food & Agriculture*, *Biomedical Research*, *Engineering & Technology*, *Materials Science* and *Computer Science*. The remaining fields have below-average levels of research activity.

Cooperation Profile

Figure 3.21 shows the cooperation profile of this state. Karnataka has strong preference for cooperation in *Mathematics*, *Chemistry*, *Biomedical Research*, *Materials Science* and *Computer Science*.

Evidently, there are important differences between the specialization and cooperation profiles. For instance, research activity in *Physics* is above-average, but cooperation is about the average. Research activity in *Food & Agriculture* is above-average, but cooperation is below-average. Again, research activity in *Engineering & Technology* is above-average, but cooperation is just below-average.

Figure 3.22 shows bidirectional affinities of Karnataka with its ten significant partners. The most important partners are Tamilnadu, Maharashtra and Andhra. The preferred fields of cooperation with these states are:

Tamilnadu : *Materials Science* (*AFI* = 40.5%), *Physics* (*AFI* = 29.6%), *Chemistry* (*AFI* = 16.9%), *Engineering & Technology* (*AFI* = 22.2%)

Maharashtra : *Biomedical Research* (*AFI* = 32.0%), *Clinical Medicine* (*AFI* = 25.8%), *Computer Science* (*AFI* = 25.0%), *Physics* (*AFI* = 19.6%)

Andhra : *Food & Agriculture* (*AFI* = 33.0%), *Chemistry* (*AFI* = 29.0%), *Materials Science* (*AFI* = 21.6%), *Biomedical Research* (*AFI* = 20.0%), *Engineering & Technology* (*AFI* = 19.4%)

Table 3.14
Publication Output and Interstate Cooperation in Science Fields

No. of Articles	5375
No. of Interstate Cooperation Links	583
No. of International Links	573
No. of States having at least one Link	20
Domesticity Index (%)	10.84
Centrality Index	0.353
Internationalization Index (%)	10.66

Field	*No. of Articles*	*No. of Links*	*Domesticity Index (%)*
Mathematics	119	17	14.29
Physics	1373	179	13.04
Chemistry	918	124	13.51
Biology	205	12	5.85
Earth & Atmospheric Science	129	44	38.65
Food & Agriculture	215	9	4.19
Clinical Medicine	529	31	5.86
Biomedical Research	612	50	8.17
Engineering & Technology	554	72	13.00
Materials Science	267	37	13.86
Computer Science	74	8	10.81
Total	5375	583	10.84

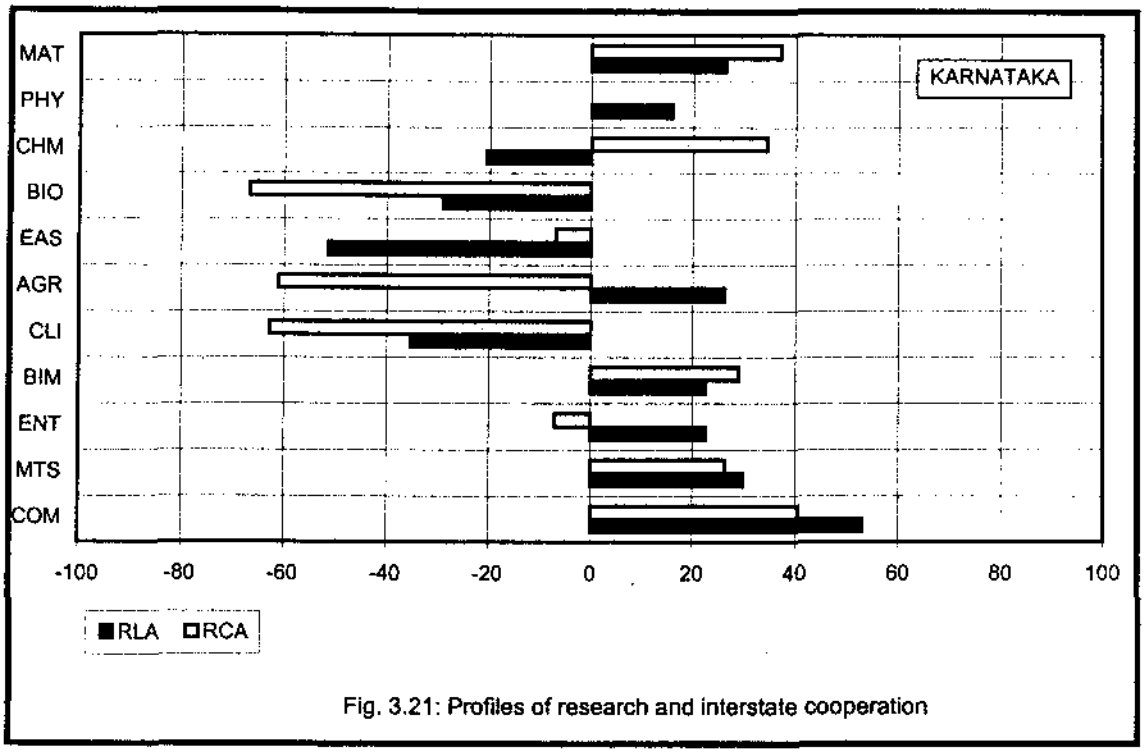

Fig. 3.21: Profiles of research and interstate cooperation

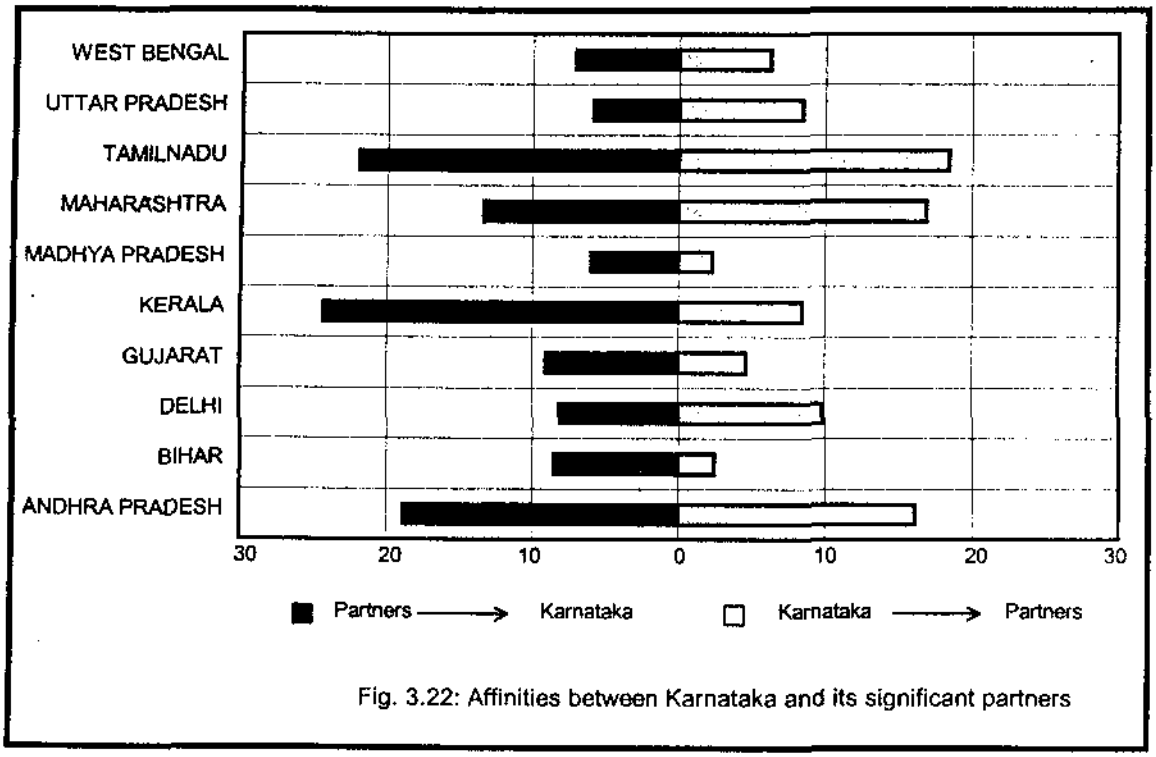

Fig. 3.22: Affinities between Karnataka and its significant partners

Kerala

Kerala contributed 1729 articles to the mainstream journals covered by the *Science Citation Index* during the five-year period: 1990-1994. This state has greater orientation towards intra-country cooperation (*Domesticity Index* = 19.2%) than towards international cooperation (*Internationalization Index* = 16.5%). It has cooperation links with fourteen states.

Table 3.15 presents the data on publication output and cooperation links of Kerala. This state attracts maximum level of cooperation in *Engineering & Technology* (*Domesticity Index* = 31.5%) and lowest level of cooperation in *Mathematics* (*Domesticity Index* = 0).

Research Profile

Figure 3.23 depicts the calculated specialization profile of Kerala. Above average values of specialization index are observed for *Chemistry*, *Biology*, *Earth & Atmospheric Science*, *Clinical Medicine* and *Materials Science*. Below-average values are observed for the remaining fields. *Materials Science* is the most important strength of this state, whereas *Computer Science* is the most important weakness.

Cooperation Profile

The cooperation profile of this state (Figure 3.23) indicates its strong preference for interstate cooperation in *Chemistry*, *Biology* and *Engineering & Technology*; near average orientation towards cooperation in *Earth & Atmospheric Science*, *Materials Science* and below – average orientation towards cooperation in the remaining fields.

Obviously, there are important differences between the two profiles. For example, *Clinical Medicine* has above-average level of research activity, but it has below-average

level of cooperation. Research activity in *Materials Science* is quite high, but cooperation is about the average. Research activity in *Engineering & Technology* is below-average, but cooperation is above-average.

Figure 3.24 depicts bidirectional affinities of Kerala towards its eight significant partners. Karnataka, Tamilnadu and U.P. are its three most important partners. Together, these three states account for about two thirds of cooperation links of Kerala. The preferred fields of cooperation with these states are:

Karnataka : *Chemistry* (*AFI* = 34.4%), *Earth & Atmospheric Science* (*AFI* = 26.3%), *Engineering & Technology* (*AFI* = 25.0%), *Materials Science* (*AFI* = 36.3%)

Tamilnadu : *Food & Agriculture* (*AFI* = 75.0%), *Biology* (*AFI* = 40.0%), *Clinical Medicine* (*AFI* = 38.1%), *Engineering & Technology* (*AFI* = 22.2%)

U.P. : *Engineering & Technology* (*AFI* = 25.0%), *Clinical Medicine* (*AFI* = 23.8%), *Chemistry* (*AFI* = 19.3%)

Table 3.15
Publication Output and Interstate Cooperation in Science Fields

No. of Articles	1729
No. of Interstate Cooperation Links	332
No. of International Links	285
No. of States having at least one Link	14
Domesticity Index (%)	19.20
Centrality Index	0.135
Internationalization Index (%)	16.48

Field	*No. of Articles*	*No. of Links*	*Domesticity Index (%)*
Mathematics	23	0	0
Physics	253	32	12.65
Chemistry	416	61	14.66
Biology	121	15	12.40
Earth & Atmospheric Science	112	19	16.96
Food & Agriculture	46	4	8.70
Clinical Medicine	325	21	6.46
Biomedical Research	123	11	8.94
Engineering & Technology	114	36	31.58
Materials Science	120	11	9.17
Computer Science	1	1	nc
Total	1729	332	19.20

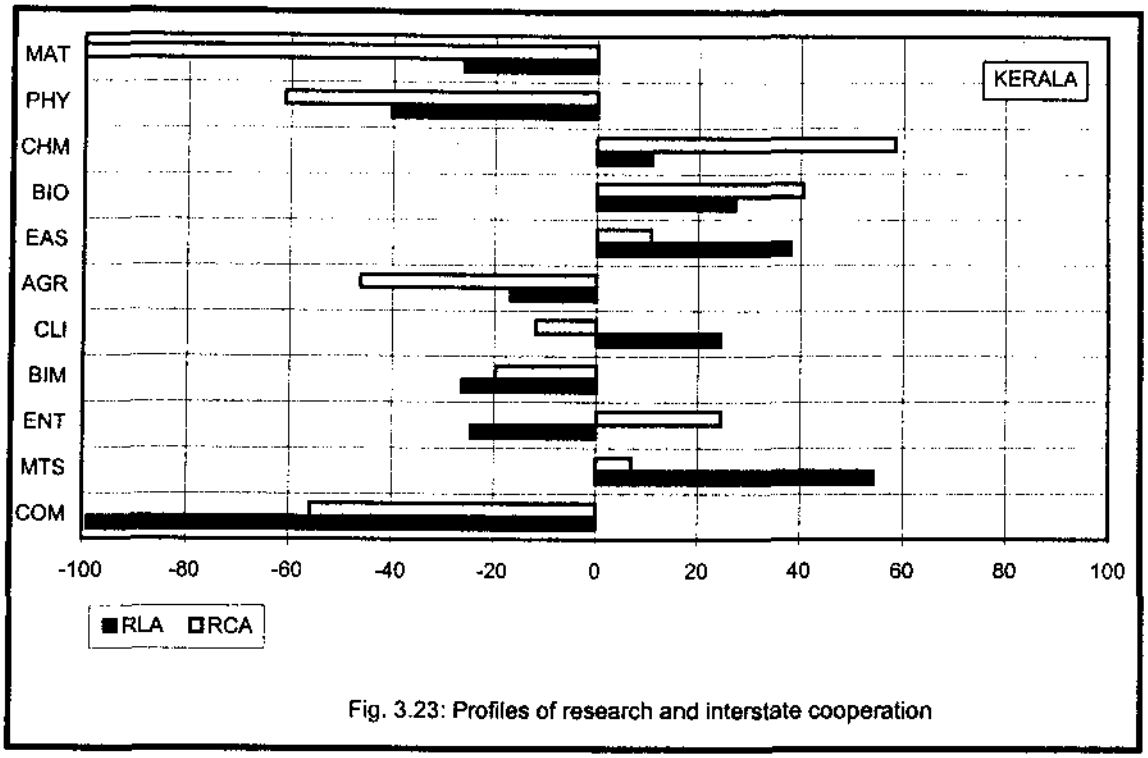

Fig. 3.23: Profiles of research and interstate cooperation

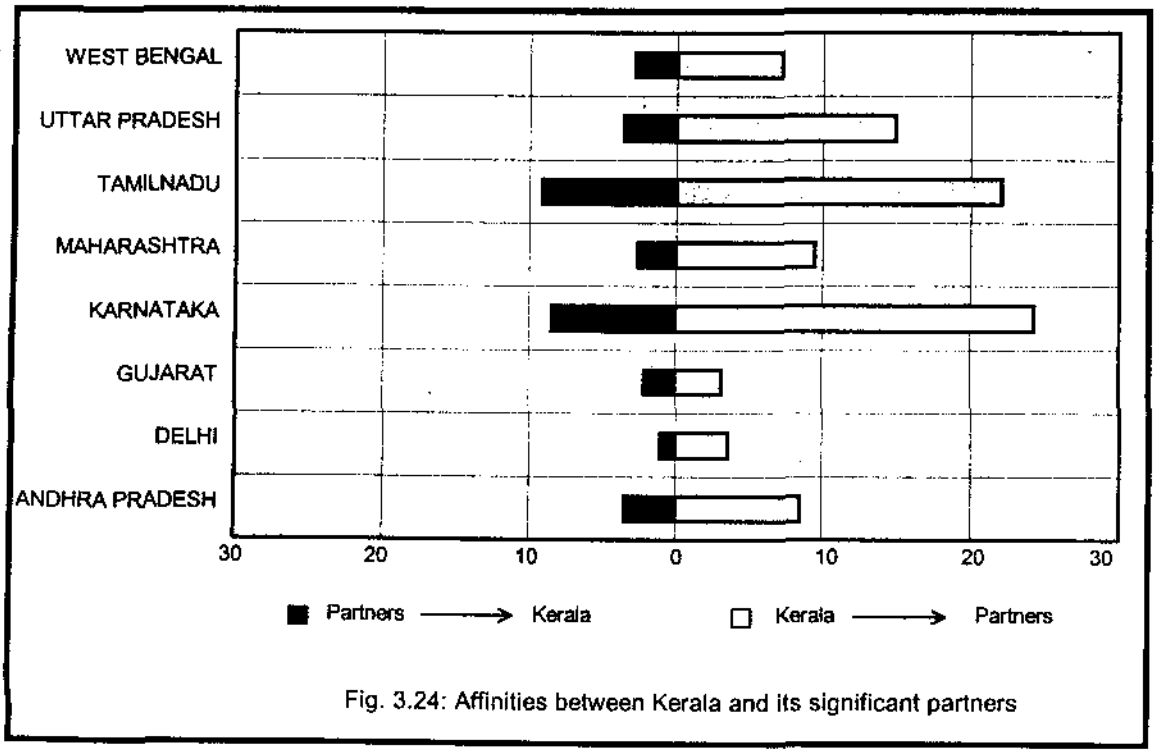

Fig. 3.24: Affinities between Kerala and its significant partners

Madhya Pradesh

During the five-year period: 1990-1994, this state contributed 1,259 articles in the journals covered by the *Science Citation Index*. Its cooperation activity may be visualized from the values of *Domesticity Index* (20.01%) and *Internationalization Index* (18.59%). Its network of cooperation is restricted to 16 states; its three most important partners are: U.P., Maharashtra and Delhi. The preferred fields of cooperation with these states are:

U.P. : *Biology* (*AFI* = 62.5%), *Clinical Medicine* (*AFI* = 34.5%), *Engineering & Technology* (*AFI* = 45.8%)

Maharashtra : *Physics* (*AFI* = 36.0%), *Materials Science* (*AFI* = 37.5%)

Delhi : *Food & Agriculture* (*AFI* = 43.0%), *Clinical Medicine* (*AFI* = 38.0%), *Biomedical Research* (*AFI* = 38.5%)

Table 3.16 presents the statistical data on publication output, cooperation links and *Domesticity Index*. Maximum cooperation is observed in *Mathematics* (*DoI* = 40%) and *Engineering & Technology* (*DoI* = 38.1%), whereas minimum cooperation is observed in *Chemistry* (*DoI* = 10.3%).

Research Profile

The specialization profile of this state is shown in Figure 3.25. Above average research activities are observed in *Physics*, *Biology* and *Materials Science*. Strongly below-average activities in *Mathematics*, *Computer Science*, *Engineering & Technology* and *Food & Agriculture* and below-average activities are observed in the remaining fields.

Cooperation Profile

Cooperation profile of this state, depicted in Figure 3.25, has remarkable similarity to its specialization profile. Above-average level of cooperation is observed in *Physics* and *Materials Science*, and below-average level of cooperation in all other fields, except *Clinical Medicine*, for which the level of cooperation is about the average.

Figure 3.26 depicts bidirectional affinities of this state with its eleven significant partners. This figure is self-explanatory and needs no elaboration.

Table 3.16
Publication Output and Interstate Cooperation in Science Fields

No. of Articles	1259
No. of Interstate Cooperation Links	252
No. of International Links	234
No. of States having at least one Link	16
Domesticity Index (%)	20.01
Centrality Index	0.155
Internationalization Index (%)	18.59

Field	*No. of Articles*	*No. of Links*	*Domesticity Index (%)*
Mathematics	10	4	40.0
Physics	344	108	31.40
Chemistry	331	30	9.06
Biology	78	8	10.27
Earth & Atmospheric Science	47	12	25.57
Food & Agriculture	23	7	30.43
Clinical Medicine	161	29	18.01
Biomedical Research	107	13	12.15
Engineering & Technology	63	24	38.10
Materials Science	52	16	30.77
Computer Science	6	1	16.67
Total	1259	252	20.01

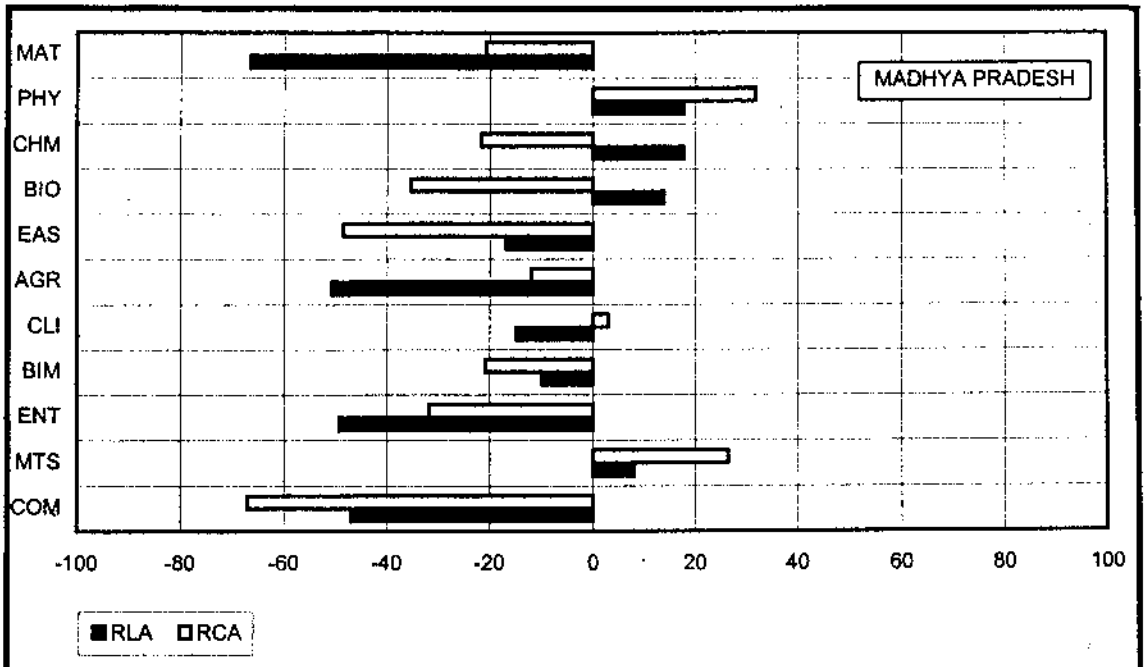

Fig. 3.25: Profiles of research and interstate cooperation

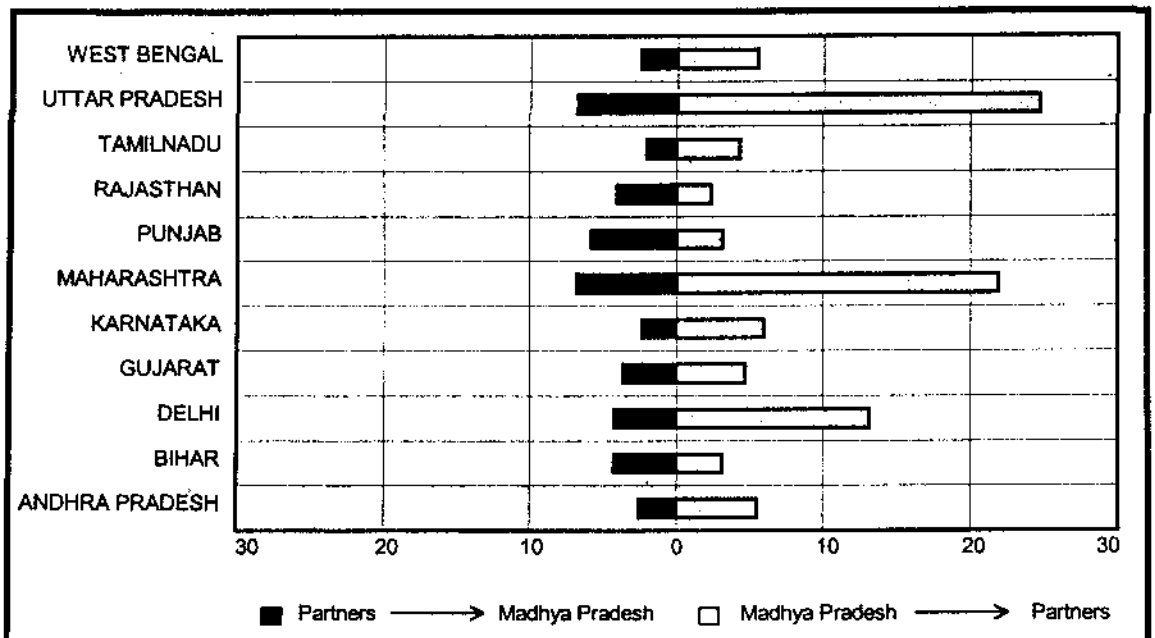

Fig. 3.26: Affinities between Madhya Pradesh and its significant partners

Maharashtra

Maharashtra occupies a prominent position in the scientific map of India. During the five-year period: 1990-1994, this state contributed 8453 articles to the *SCI*-covered journals, involving 809 inter-state and 728 cooperation links. Its cooperation network spans 22 states – only five states (Andaman, Himachal, Manipur, Mizoram, Sikkim) did not have any cooperation with Maharashtra.

Table 3.17 presents the statistical data on publication output and cooperation links of this state. Inter-field differences in cooperation are not as strong as in the case of many other states. The values of *Domesticity Index* vary from a low of 4.9% for *Chemistry* to a high of 14.5% for *Earth & Atmospheric Science*.

Research Profile

Figure 3.27 depicts the specialization profile of Maharashtra. It can be easily seen that no single field dominates its research profile. Above-average level of activity is observed in *Mathematics*, *Physics* and *Chemistry*, about average level of activity in *Engineering & Technology* and *Clinical Medicine*, and below-average level of activity in the remaining fields.

Cooperation Profile

Figure 3.27 depicts the cooperation profile of this state. It can be easily seen that the cooperation profile is quite similar to its research profile. Above-average level of cooperation is observed in *Mathematics*, *Physics* and *Biomedical Research*; about average level of cooperation in *Chemistry* and *Clinical Medicine* and below-average level of cooperation in the remaining fields.

Table 3.17
Publication Output and Interstate Cooperation in Science Fields

No. of Articles	8453
No. of Interstate Cooperation Links	809
No. of International Links	728
No. of States having at least one Link	22
Domesticity Index (%)	9.57
Centrality Index	0.402
Internationalization Index (%)	8.61

Field	*No. of Articles*	*No. of Links*	*Domesticity Index (%)*
Mathematics	203	22	10.84
Physics	2320	327	14.09
Chemistry	2167	107	4.94
Biology	176	12	6.82
Earth & Atmospheric Science	303	44	14.52
Food & Agriculture	90	10	11.11
Clinical Medicine	1254	78	6.22
Biomedical Research	609	55	9.03
Engineering & Technology	692	72	10.40
Materials Science	253	29	11.46
Computer Science	50	7	14.00
Total	8453	809	9.57

It can be easily seen that research and cooperation profiles of this state are more or less similar; but there are also important differences. *Chemistry* has above-average level of research activity, but about average level of cooperation. On the other hand *Computer Science* has below-average level of research activity, but about average level of cooperation. *Biomedical Research* has below-average level of research activity, but above-average level of cooperation.

Figure 3.28 indicates bidirectional affinities of Maharashtra with its twelve significant partners. No single state dominates its cooperation profile. Karnataka, Gujarat and U.P. are its three most important partners. Together, these states account for about one-third of its cooperation links. The preferred fields of cooperation with these states are:

Karnataka	:	*Biomedical Research* (*AFI* = 22.2%)
Gujarat	:	*Mathematics* (*AFI* = 22.7%)
U.P.	:	*Biomedical Research* (*AFI* = 25.0%), *Computer Science* (*AFI* = 42.9%) and *Clinical Medicine* (*AFI* = 12.8%).

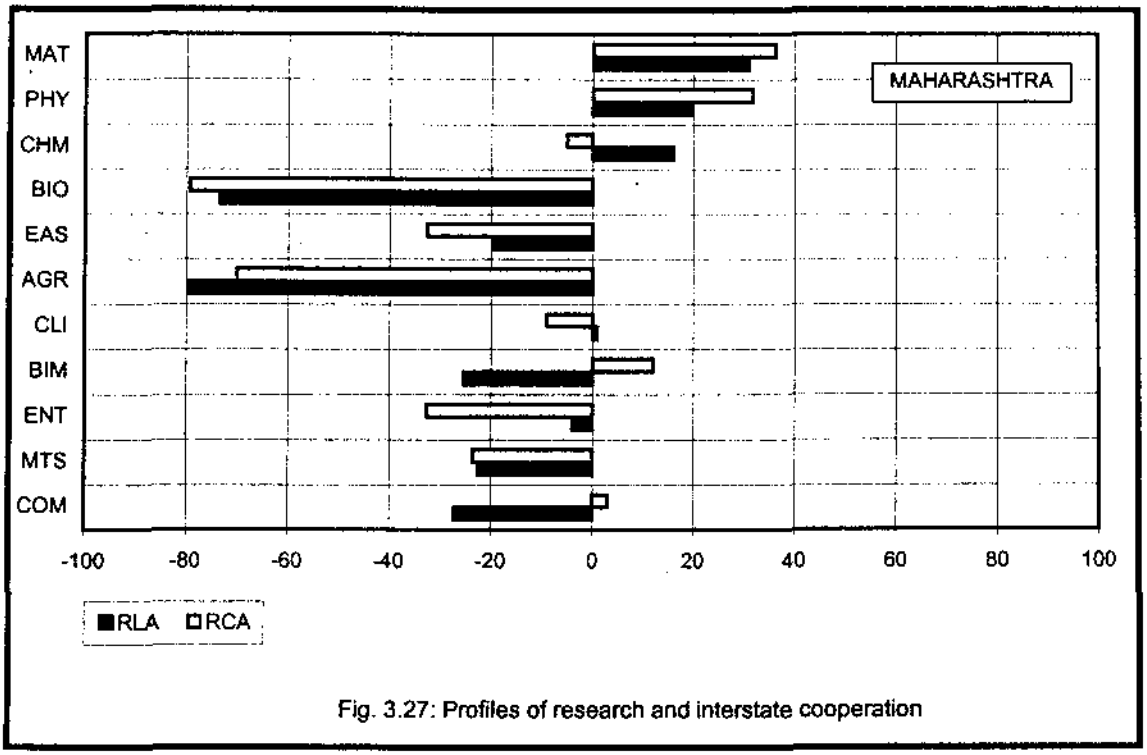

Fig. 3.27: Profiles of research and interstate cooperation

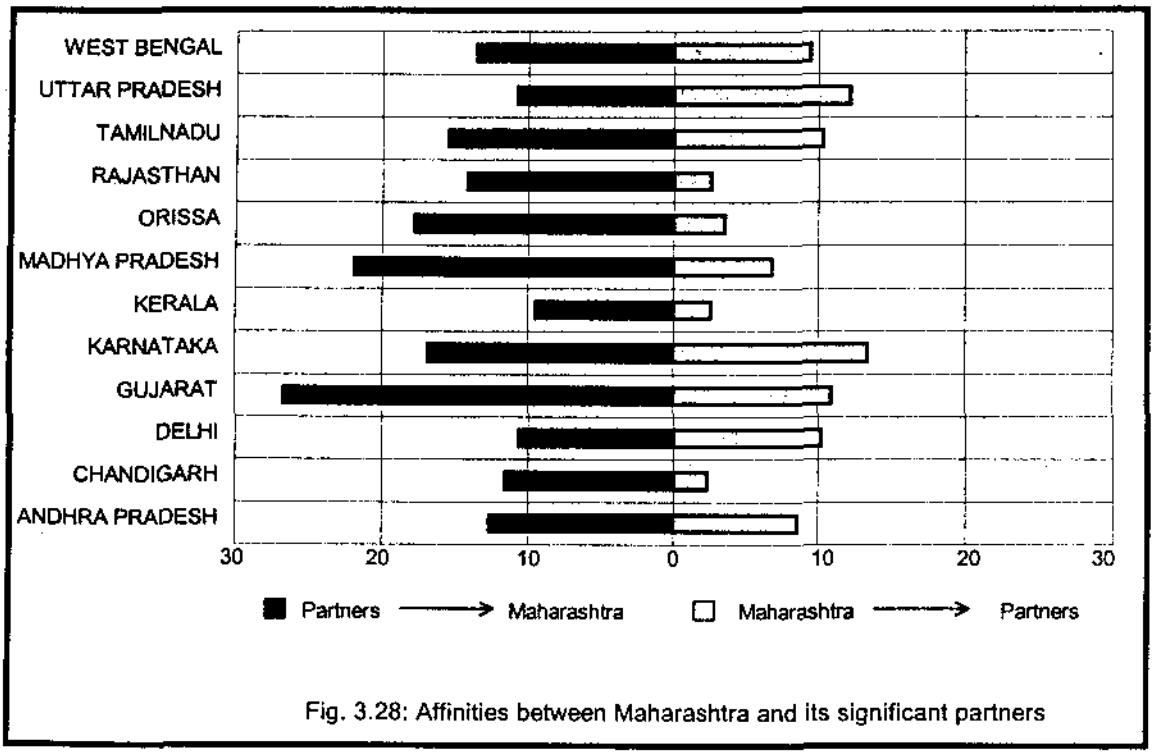

Fig. 3.28: Affinities between Maharashtra and its significant partners

Manipur

Manipur is a small state; it contributed 114 articles to the mainstream journals covered in the *Science Citation Index* in five-years: 1990-1994. It is quite active in developing cooperation links, both within and outside the country. Because of its small size, the cooperation network of Manipur is restricted to ten states. It resides in the periphery of interstate cooperation network. The value of *Bonacich Eigenvector Centrality* is 0.015, which is quite low.

Table 3.18 presents the data on publication output and cooperation links of this state. The value of *Domesticity Index* varies from a low of 16.7% for *Biology* to a high of 70.0% for *Clinical Medicine*.

Research Profile

Figure 3.29 presents the research profile of this state, which is dominated by *Physics*. About-average level of research activity is observed in *Chemistry*, *Biology* and *Food & Agriculture*. Research activities in the remaining fields are quite low.

Cooperation Profile

Figure 3.29 depicts the cooperation profile of this state, which is quite different from the research profile. This state has strong preference for cooperation in *Mathematics*, *Chemistry*, *Clinical Medicine* and *Food & Agriculture* – all these fields have below-average level of research activity. This state has about average preference for cooperation in *Physics* and *Materials Science*.

The only important partner of this state is West Bengal, accounting for about 50% of its all cooperation links. The preferred fields for cooperation with West Bengal are: *Physics* (*AFI* = 66.7%) and *Chemistry* (*AFI* = 35.5%).

Table 3.18
Publication Output and Interstate Cooperation in Science Fields

No. of Articles	114
No. of Interstate Cooperation Links	40
No. of International Links	31
No. of States having at least one Link	10
Domesticity Index (%)	35.09
Centrality Index	0.015
Internationalization Index (%)	27.19

Field	*No. of Articles*	*No. of Links*	*Domesticity Index (%)*
Mathematics	1	1	nc
Physics	62	15	24.19
Chemistry	22	9	40.91
Biology	6	1	16.67
Earth & Atmospheric Science	2	2	nc
Food & Agriculture	4	3	nc
Clinical Medicine	10	7	70.00
Biomedical Research	4	0	nc
Engineering & Technology	0	0	na
Materials Science	1	0	nc
Computer Science	0	0	nc
Total	114	40	35.09

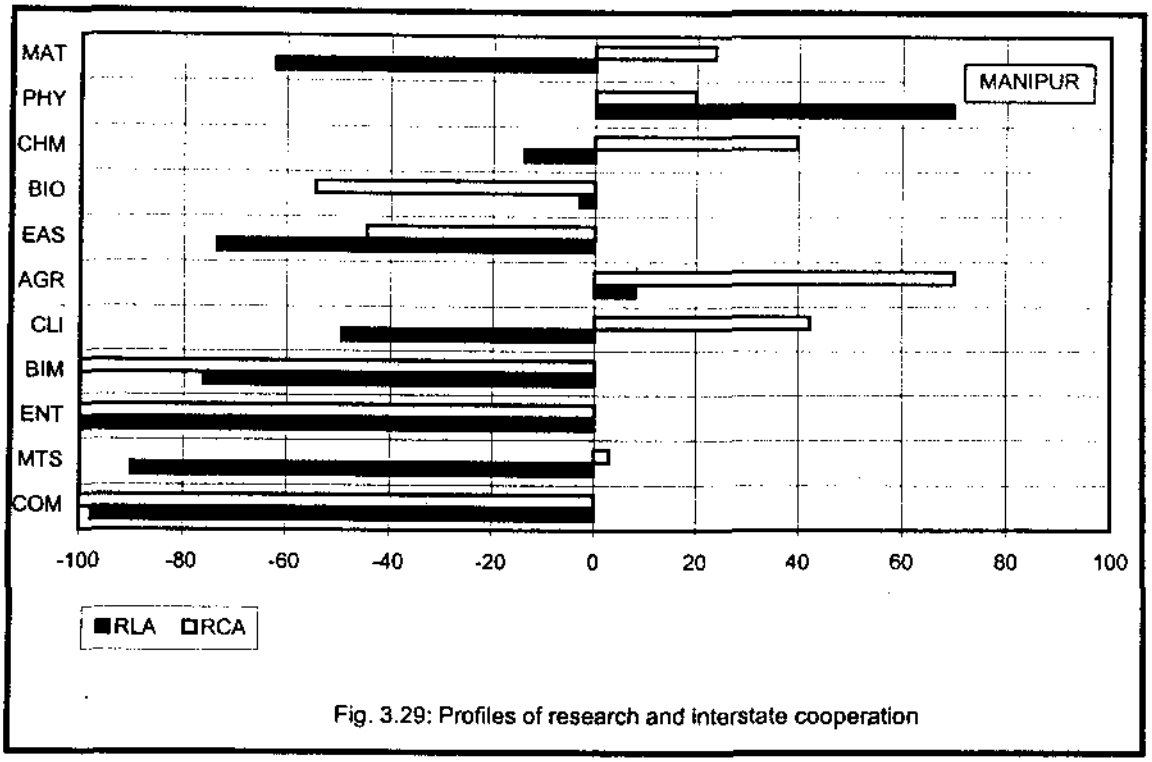

Fig. 3.29: Profiles of research and interstate cooperation

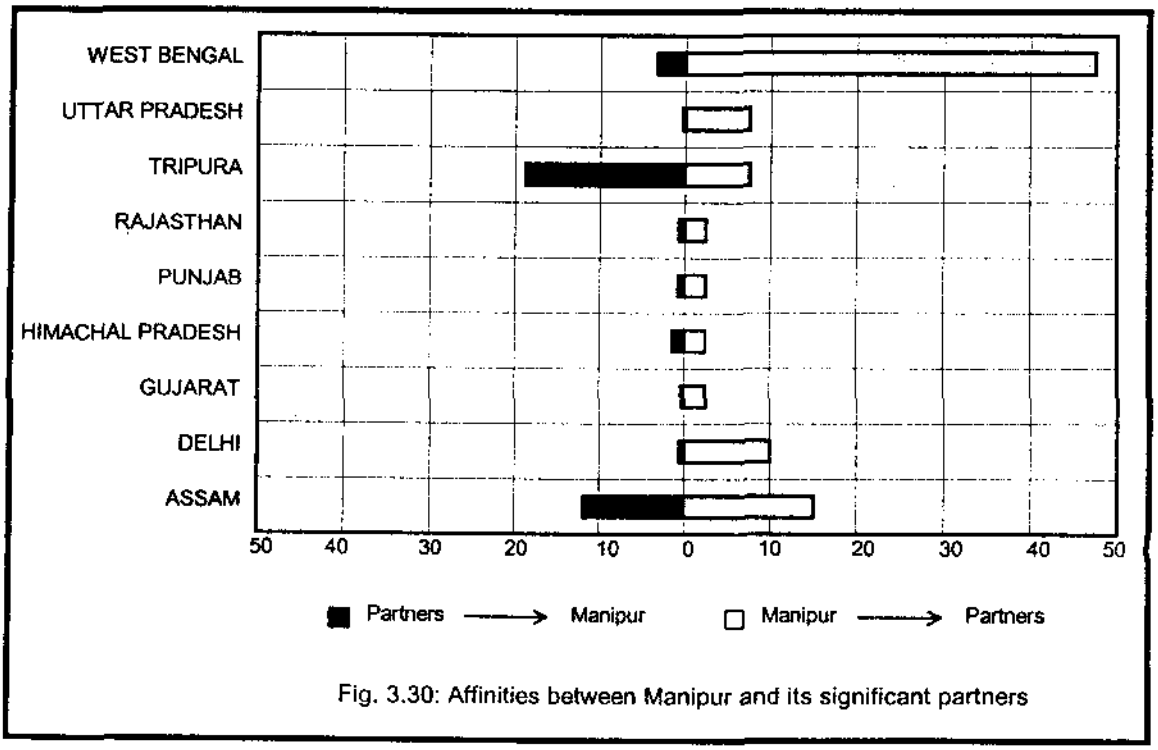

Fig. 3.30: Affinities between Manipur and its significant partners

Meghalaya

Meghalaya had contributed 380 articles in the mainstream journals covered in the *Science Citation Index* during the five-year period: 1990-1994. These articles had involved 54 cooperation links with other states in the country and 45 cooperation links outside the country. Its cooperation network is limited to only 11 states. Its most important partners are West Bengal, UP and Maharashtra.

Table 3.19 presents the data on publication output and cooperation links of this state.

Research Profile

Figure 3.31 depicts its research profile, which is characterized by strong orientation of its research activities towards *Chemistry*, *Biology* and *Biomedical Research*.

Cooperation Profile

The cooperation profile of this state (Fig. 3.31) is almost identical to its research profile.

Figure 3.32 shows bidirectional affinities of this states with its eight significant partners. Its most important partners and preferred fields of cooperation are listed below:

West Bengal; : *Physics* (*AFI* = 37.5%), *Chemistry* (*AFI* = 33.3%)

U.P. : *Physics* (*AFI* = 37.5%), *Biology* (*AFI* = 42.9%), *Chemistry* (*AFI* = 16.7%)

Maharashtra : *Earth & Atmospheric Science* (2 out of 2 links)

Table 3.19
Publication Output and Interstate Cooperation in Science Fields

No. of Articles	380
No. of Interstate Cooperation Links	54
No. of International Links	45
No. of States having at least one Link	11
Domesticity Index (%)	14.21
Centrality Index	0.031
Internationalization Index (%)	11.84

Field	*No. of Articles*	*No. of Links*	*Domesticity Index (%)*
Mathematics	5	1	20.00
Physics	98	16	16.33
Chemistry	136	12	8.82
Biology	47	7	14.89
Earth & Atmospheric Science	10	2	20.00
Food & Agriculture	10	0	0.00
Clinical Medicine	4	0	nc
Biomedical Research	53	6	11.32
Engineering & Technology	5	0	0.00
Materials Science	1	1	nc
Computer Science	0	0	na
Total	380	54	14.21

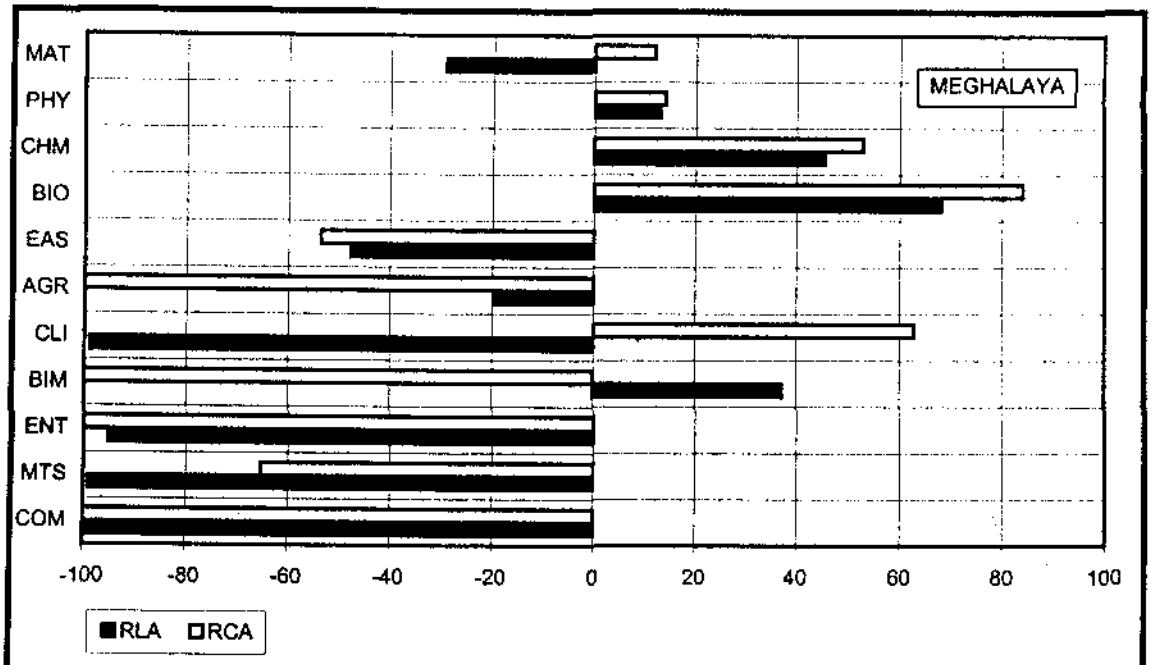

Fig. 3.31: Profiles of research and interstate cooperation

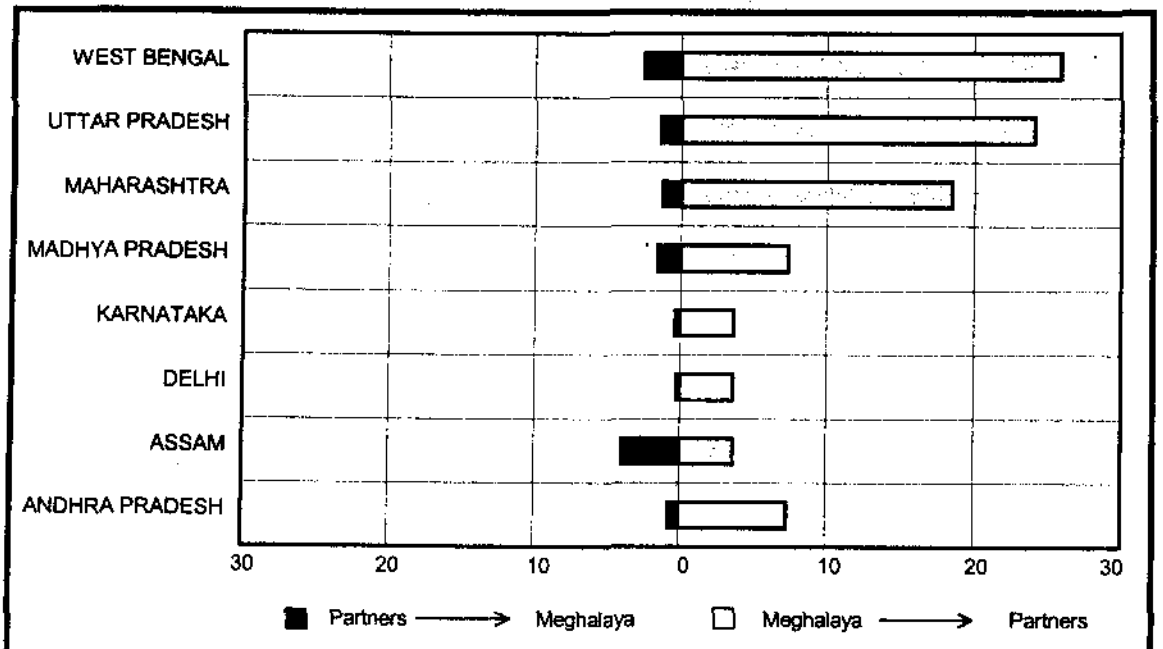

Fig. 3.32: Affinities between Meghalaya and its significant partners

Orissa

Orissa had published 970 articles in the *SCI*-covered journals, involving 163 interstate and 140 international cooperation links. Its cooperation network encompasses twenty states, among which the most important partners are West Bengal and Maharashtra. These two states account for more than 40% of Orissa's interstate cooperation links. The preferred fields of cooperation with these states are:

West Bengal : *Mathematics* (*AFI* = 10.0%), *Physics* (*AFI* = 20.0%), *Chemistry* (*AFI* = 25.0%), *Engineering & Technology* (*AFI* = 57.0%)

Maharashtra : *Physics* (*AFI* = 30.0%)

Table 3.20 presents the statistical data on publication output and interstate cooperation links of this state. There are sharp variations in the incidence of cooperation links in different fields. The value of *Domesticity Index* varies from a low of 7.0% for *Chemistry* to a high of 54.5% for *Mathematics*.

Research Profile

Figure 3.33 depicts the specialization profile of Orissa. The research activities of this state are concentrated in *Physics* and *Food & Agriculture*. All other fields, except *Chemistry*, show below-average levels. Particular weaknesses are identified for *Mathematics*, *Clinical Medicine*, *Biomedical Research*, *Materials Science* and *Computer Science*. About average level of research activity is observed in *Chemistry*.

Cooperation Profile

The cooperation profile of this state is more or less similar to its research profile. Notable differences are observed for *Mathematics* and *Chemistry*. The level of research activity in *Mathematics* is below-average, whereas that of cooperation is above-average.

The level of cooperation in *Chemistry* is below-average, whereas that of research is about-average.

Figure 3.34 depicts bidirectional affinities of this state with its ten significant partners. This figure is self-explanatory and need no elaboration.

Table 3.20
Publication Output and Interstate Cooperation in Science Fields

No. of Articles	970
No. of Interstate Cooperation Links	163
No. of International Links	140
No. of States having at least one Link	20
Domesticity Index (%)	16.80
Centrality Index	0.088
Internationalization Index (%)	14.43

Field	*No. of Articles*	*No. of Links*	*Domesticity Index (%)*
Mathematics	11	5	54.45
Physics	367	80	21.80
Chemistry	229	16	6.99
Biology	64	5	7.81
Earth & Atmospheric Science	36	9	25.00
Food & Agriculture	42	6	14.29
Clinical Medicine	70	10	14.29
Biomedical Research	49	5	10.20
Engineering & Technology	64	21	32.81
Materials Science	20	3	15.00
Computer Science	2	0	nc
Total	970	163	16.80

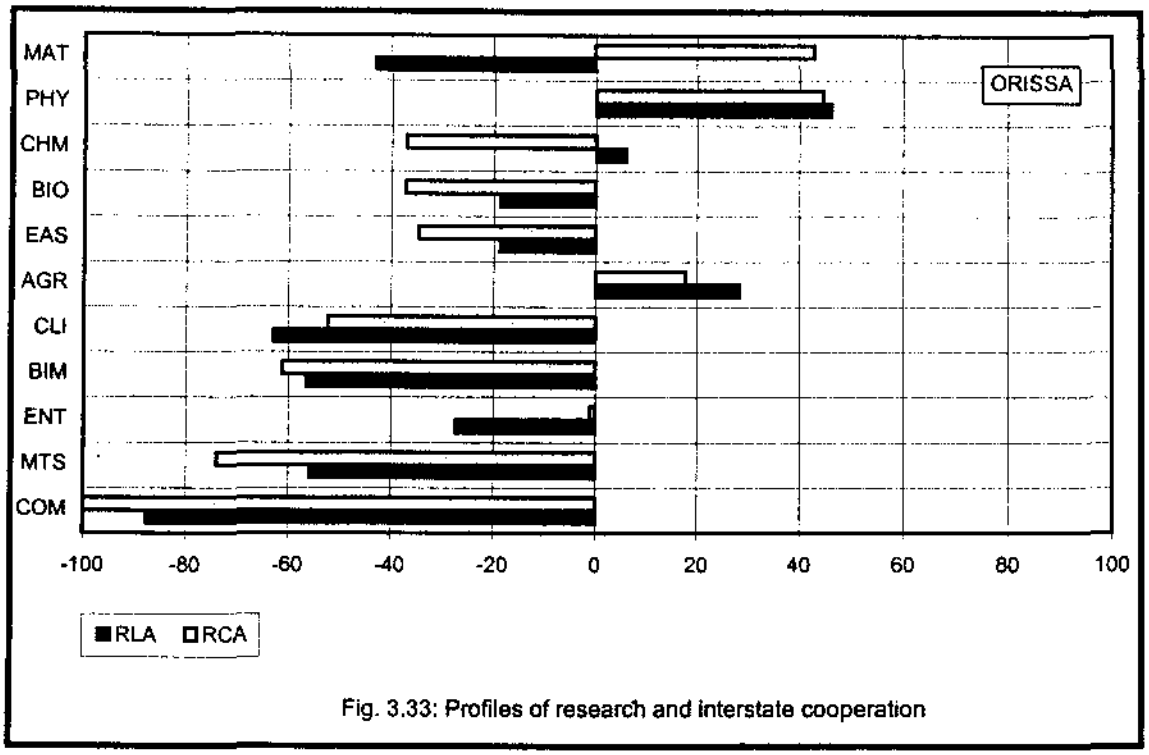

Fig. 3.33: Profiles of research and interstate cooperation

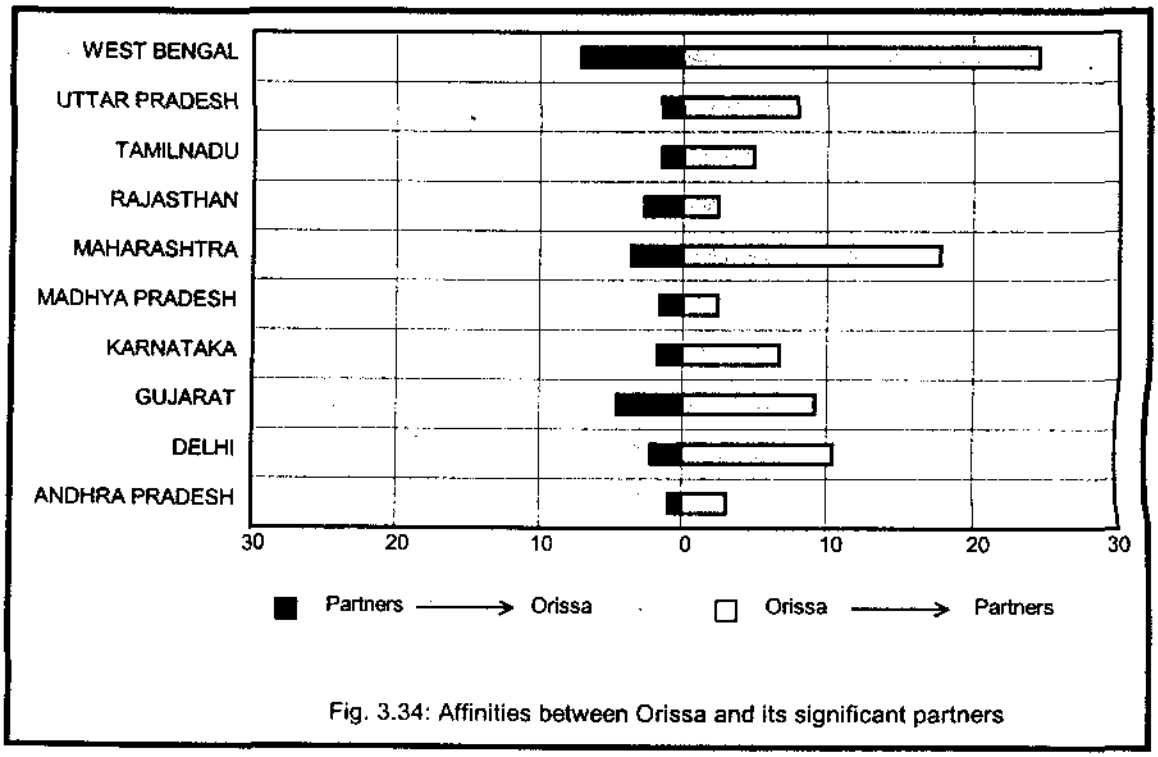

Fig. 3.34: Affinities between Orissa and its significant partners

Pondicherry

This state contributed 288 articles to the mainstream journals, covered by the *Science Citation Index* during 1990-1994. These articles involved 53 interstate and 46 international cooperation links. Because of its small size, its cooperation network is confined to only 14 states. Its major partners are Tamilnadu and Andhra Pradesh.

The statistical data on publication output and cooperation links of this state are presented in Table 3.21.

Research Profile

Figure 3.35 depicts the specialization profile of this state which is characterized by the dominating orientation of its research activities towards *Clinical Medicine*. Strongly below average activities are observed in all the other fields, except *Biology* and *Biomedical Research*. The values of specialization index for these two fields are slightly above the average.

Cooperation Profile

The cooperation profile of this state indicates its strong preference for cooperation with other states in *Clinical Medicine*, *Biology*, *Biomedical Research* and *Chemistry*.

Figure 3.36 shows bidirectional affinities of this state with its nine significant partners. Tamilnadu and Andhra are its two major partners. The preferred fields for cooperation with these states are:

Tamilnadu : *Chemistry* (*AFI* = 22.2%), *Clinical Medicine* (*AFI* = 43.5%)

Andhra : *Chemistry* (*AFI* = 66.7%), *Earth & Atmospheric Science* (All the cooperation links are with this state)

Table 3.21
Publication Output and Interstate Cooperation in Science Fields

No. of Articles	288
No. of Interstate Cooperation Links	53
No. of International Links	46
No. of States having at least one Link	14
Domesticity Index (%)	18.40
Centrality Index	0.034
Internationalization Index (%)	15.97

Field	*No. of Articles*	*No. of Links*	*Domesticity Index (%)*
Mathematics	4	1	nc
Physics	22	2	9.09
Chemistry	32	9	28.12
Biology	17	4	23.53
Earth & Atmospheric Science	5	3	60.00
Food & Agriculture	4	1	nc
Clinical Medicine	153	23	15.03
Biomedical Research	29	4	13.79
Engineering & Technology	7	1	14.29
Materials Science	6	1	16.67
Computer Science	0	0	na
Total	288	53	18.40

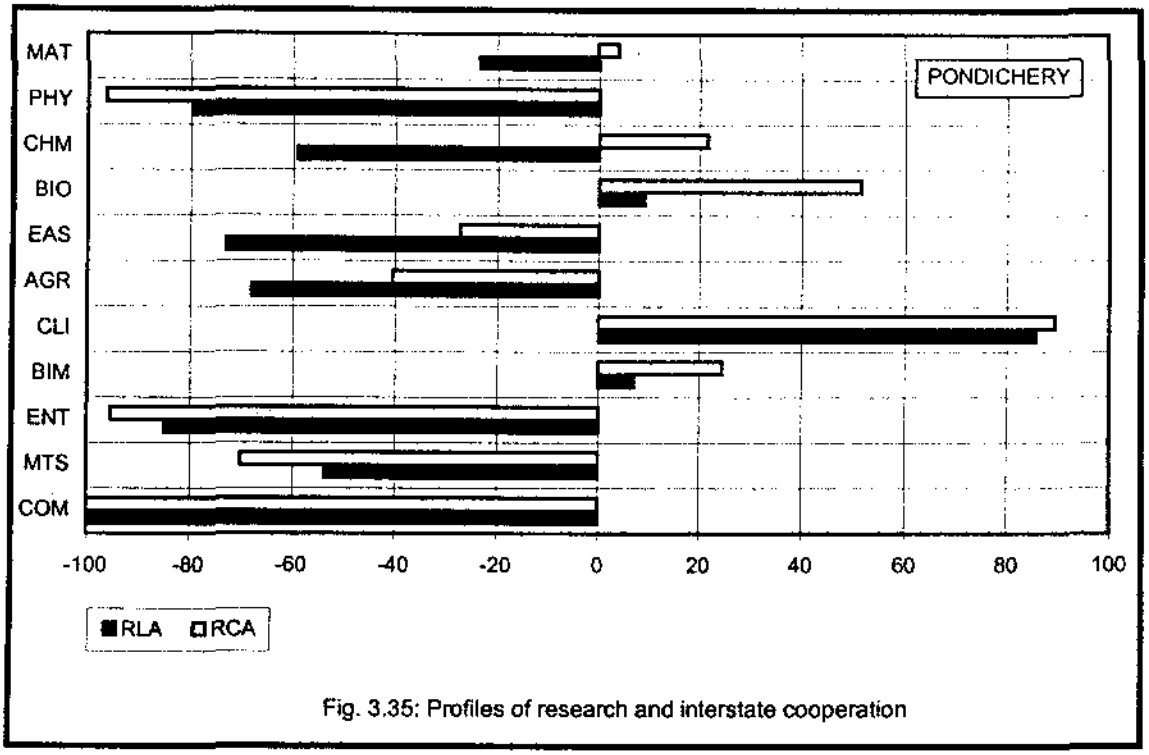

Fig. 3.35: Profiles of research and interstate cooperation

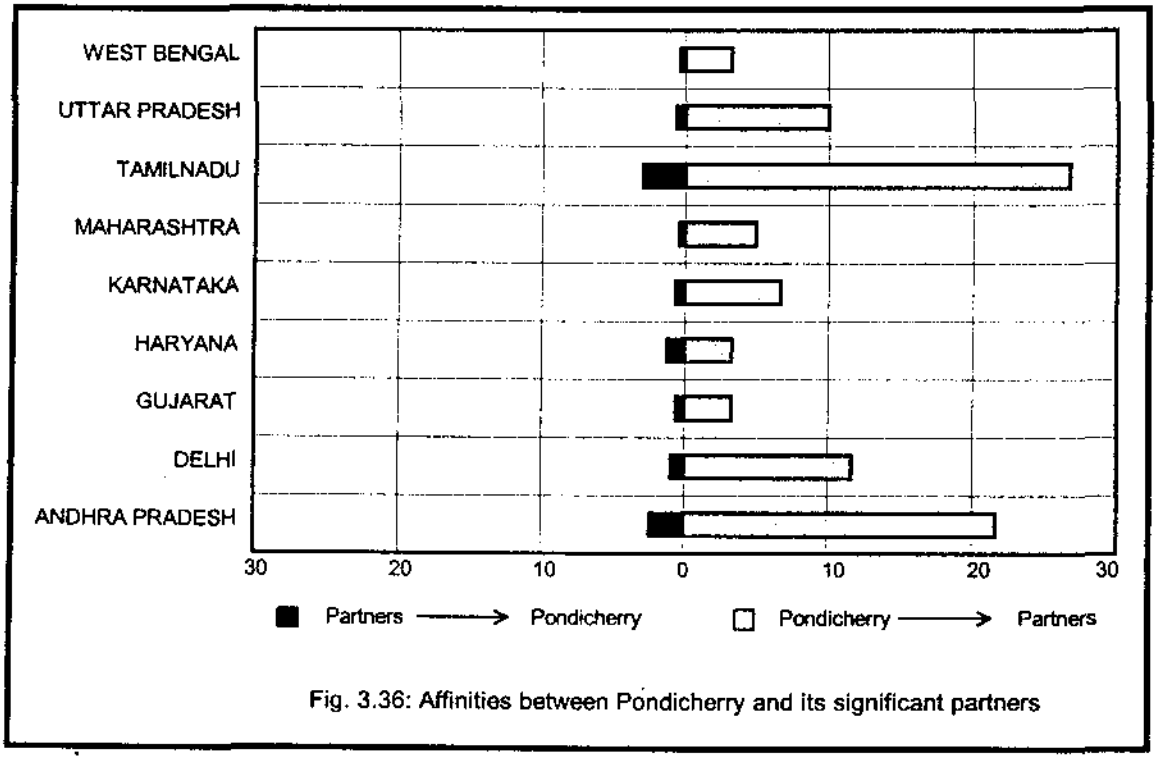

Fig. 3.36: Affinities between Pondicherry and its significant partners

Punjab

During the five-year period: 1990-1994, Punjab had published 866 articles in the *SCI*-covered journals, involving 138 interstate and 128 international cooperation links. The cooperation network of Punjab is rather limited; it spans only 16 states. Its neighbour, Jammu & Kashmir, had published only 376 articles (less than half of Punjab), but its cooperation network spans 19 states.

Table 3.22 presents the data on publication output and cooperation links of this state. There are strong inter - field differences in the level of cooperation. The value of *Domesticity Index* varies from a low of 0% for *Mathematics* to a high of 60.0% for *Materials Science*.

Research Profile

Figure 3.37 shows the calculated specialization profile of this state, which is characterized by strengths in *Biology*, *Food & Agriculture* and *Biomedical Research*. Weaknesses are observed in the remaining fields, except *Chemistry*, which has average level of activity.

Cooperation Profile

The cooperation profile of this state (Figure 3.37) is quite similar to its specialization profile. This state has strong preferences for cooperation in *Food & Agriculture* and *Biomedical Research*. However, *Biology* has above-average level of research activity, but below-average level of cooperation.

Figure 3.38 depicts bidirectional affinities of Punjab with its ten significant partners. Most important partners of this state are Delhi, UP and Chandigarh. The preferred fields for cooperation with these states are:

Delhi : *Chemistry* (*AFI* = 39.1%), *Food & Agriculture* (*AFI* = 18.2%), *Clinical Medicine* (*AFI* = 41.2%), *Engineering & Technology* (*AFI* = 21.4%)

U.P. : *Biomedical Research* (*AFI* = 33.3%), *Engineering & Technology* (*AFI* = 21.4%), *Physics* (*AFI* = 24.0%), *Food & Agriculture* (*AFI* = 40.9%)

Chandigarh : *Physics* (*AFI* = 28.0%), *Chemistry* (*AFI* = 17.4%), *Biomedical Research* (*AFI* = 27.5%)

Table 3.22
Publication Output and Interstate Cooperation in Science Fields

No. of Articles	866
No. of Interstate Cooperation Links	138
No. of International Links	128
No. of States having at least one Link	16
Domesticity Index (%)	15.94
Centrality Index	0.060
Internationalization Index (%)	14.78

Field	*No. of Articles*	*No. of Links*	*Domesticity Index (%)*
Mathematics	6	0	0.00
Physics	133	25	18.80
Chemistry	184	23	12.50
Biology	76	4	5.26
Earth & Atmospheric Science	25	5	20.00
Food & Agriculture	158	22	13.92
Clinical Medicine	130	17	13.08
Biomedical Research	100	18	18.00
Engineering & Technology	31	14	45.16
Materials Science	10	6	30.00
Computer Science	0	0	nc
Total	866	138	15.94

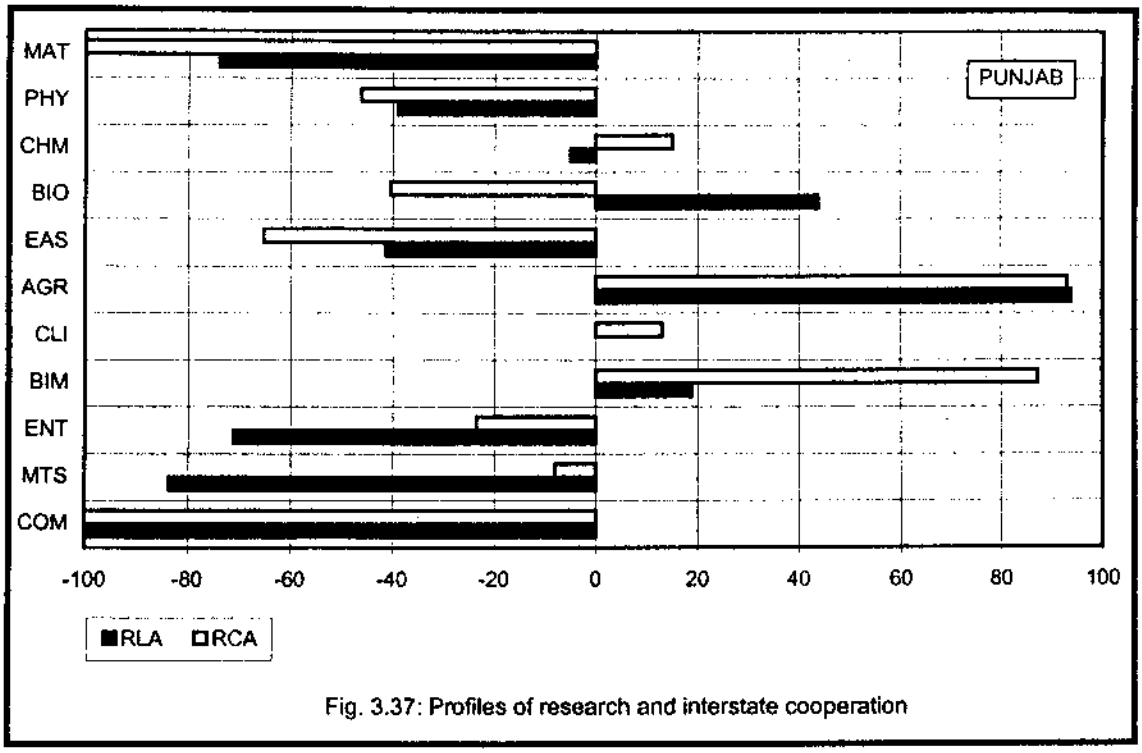

Fig. 3.37: Profiles of research and interstate cooperation

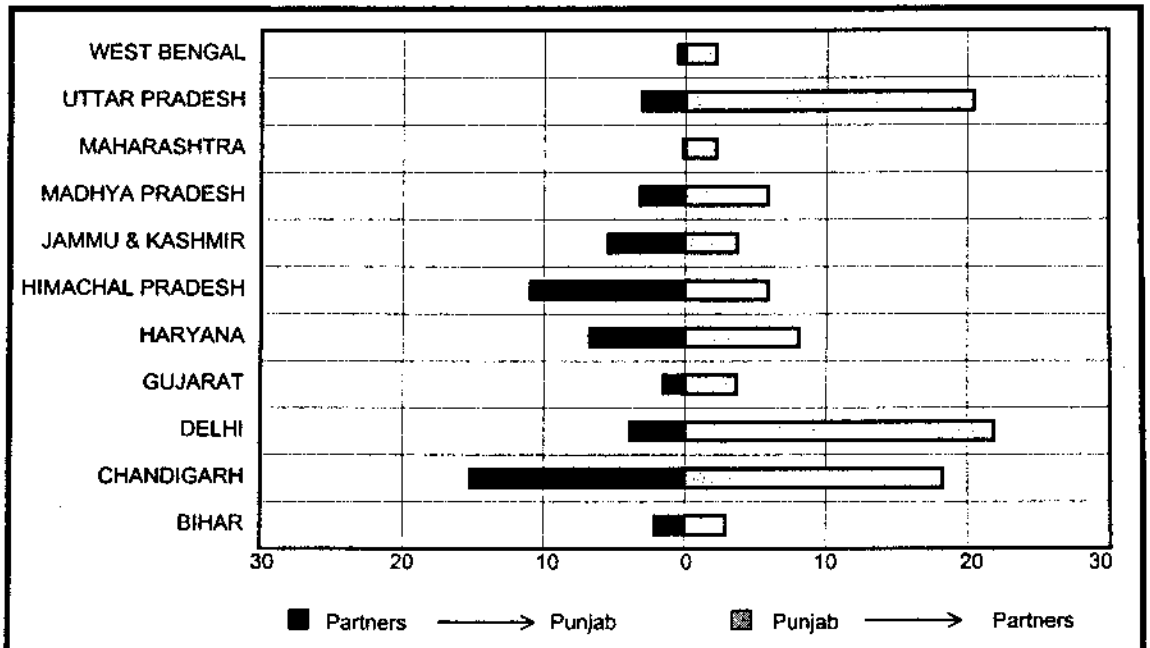

Fig. 3.38: Affinities between Punjab and its significant partners

Rajasthan

Rajasthan had contributed 1621 articles to the *SCI*-covered journals during the five-year period: 1990-1994, involving 149 interstate and 141 international cooperation links. Its intra-country cooperation network is confined to 19 states.

Table 3.23 presents the data on Rajasthan's publication output and interstate cooperation links. The propensity of this state for developing cooperation links covaries with research field. The values of *Domesticity Index* vary from a low of 6.5% for *Biology* to a high of 47.1% for *Materials Science.*

Research Profile

Figure 3.39 depicts the specialization profile of research activities of this state. The profile is characterized by strengths in *Chemistry* and *Biology* and weaknesses in the remaining fields, particularly *Mathematics, Earth & Atmospheric Science, Biomedical Research, Materials Science* and *Computer Science.*

Cooperation Profile

Figure 3.39 depicts the cooperation profile which indicates that the state prefers *Physics, Chemistry, Biology, Food & Agriculture* and *Materials Science* for cooperation with other states. This state has about average level of cooperation in *Clinical Medicine* and *Engineering & Technology.*

Figure 3.40 shows bidirectional affinities of this state with its eleven significant partners. Its most important partners are Delhi, UP and Maharashtra. These three states account for more than 55% of interstate cooperation links of Rajasthan. The preferred fields of cooperation with these states are:

UP : *Chemistry* (*AFI* = 28.8%), *Engineering & Technology* (*AFI* =

52.6%)

Delhi : *Physics* (*AFI* = 30.0%), *Clinical Medicine* ((*AFI* = *31.4%)* = 85.7%), *Engineering & Technology* (*AFI* = 31.6%), *Materials Science* (*AFI* = 50.0%)

Maharashtra : *Chemistry* (*AFI* = 29.2%), *Biology* (*AFI* = 33.3%), *Clinical Medicine* (*AFI* = 21.6%)

Table 3.23
Publication Output and Interstate Cooperation in Science Fields

No. of Articles	1021
No. of Interstate Cooperation Links	149
No. of International Links	141
No. of States having at least one Link	19
Domesticity Index (%)	14.59
Centrality Index	0.083
Internationalization Index (%)	13.81

Field	*No. of Articles*	*No. of Links*	*Domesticity Index (%)*
Mathematics	8	1	12.50
Physics	211	50	23.70
Chemistry	367	24	6.54
Biology	74	9	12.16
Earth & Atmospheric Science	23	6	26.03
Food & Agriculture	30	6	20.00
Clinical Medicine	138	14	10.14
Biomedical Research	*26*	*2*	*7.69*
Engineering & Technology	77	19	24.68
Materials Science	17	8	47.06
Computer Science	6	0	0.00
Total	1021	149	14.59

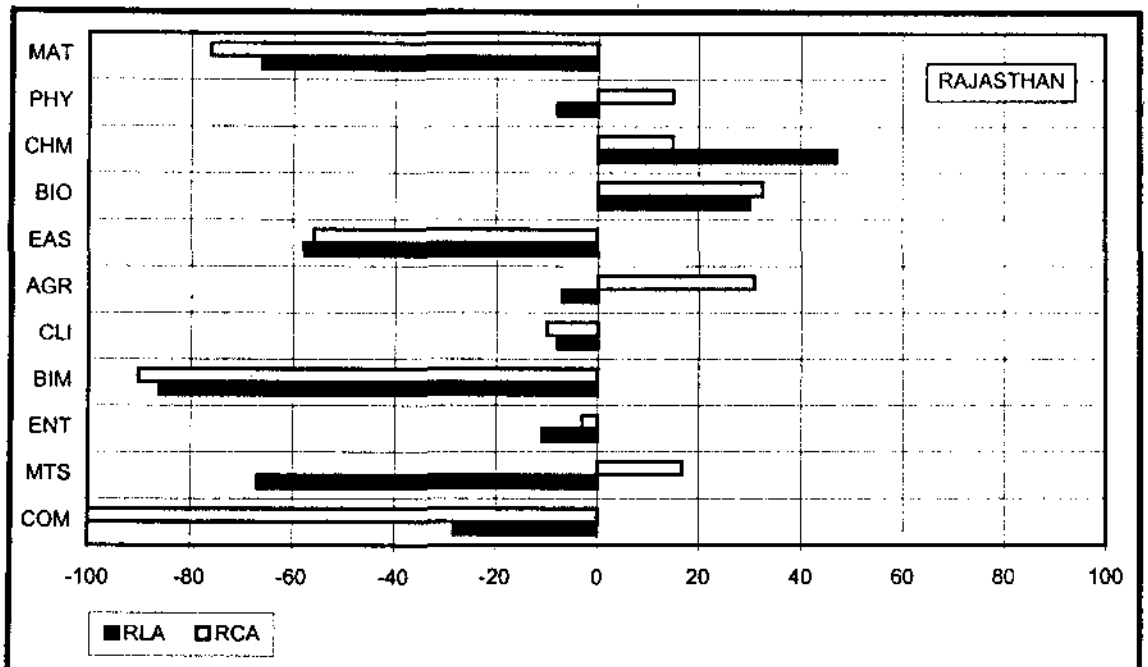

Fig. 3.39: Profiles of research and interstate cooperation

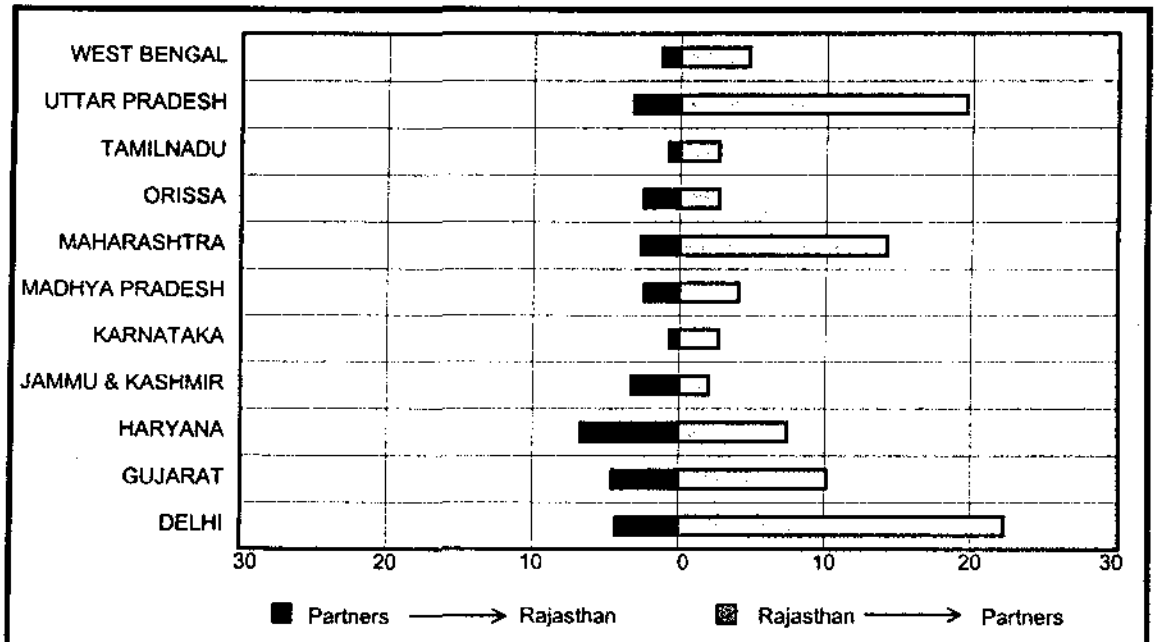

Fig. 3.40: Affinities between Rajasthan and its significant partners

Tamilnadu

Tamilnadu occupies an important position in the scientific map of India. This state ranks sixth in terms of publication output and fourth in terms of cooperation links, but the span of its cooperation network is not commensurate with its scientific size. Tamilnadu had published 4723 articles in five years, involving 566 interstate cooperation links, spanning 20 states. Compare it with Orissa, which had published only 970 articles, involving 163 interstate cooperation links, spanning 20 states.

Table 3.24 presents the data on the output of publications and cooperation links in different fields. Inter-field variations in intestate cooperation may be visualized from the values of *Domesticity Index*, which vary from a low of 5.9% for *Biomedical Research* to a high of 18.0% for *Physics*.

Research Profile

Figure 3.41 shows the specialization profile of this state. The profile is more or less balanced. Research activities in six fields (*Mathematics*, *Physics*, *Chemistry*, *Biology*, *Clinical Medicine* and *Biomedical Research* are about the national average. Strengths are observed for *Engineering & Technology*, *Materials Science* and *Computer Science*, whereas weaknesses are observed for *Earth & Atmospheric Science* and *Food & Agriculture*.

Cooperation Profile

Figure 3.41 depicts the cooperation profile of this state. It can be easily seen that this state prefers to cooperate in *Physics*, *Biology*, *Clinical Medicine* and *Materials Science*. The values of *RCA* for these fields are positive. It gives less emphasis to the remaining fields. *Mathematics* and *Materials Science* receive about average emphasis.

The differences in the two profiles are summarized below:

	Level of Activity *RLA*	Level of Cooperation *RCA*
Physics	0	+
Biology	0	-
Clinical Medicine	0	+
Engineering & Technology	+	0
Computer Science	+	-

(0) = about average, (+) = above - average, (-) = below - average

Figure 3.42 shows bidirectional affinities of Tamilnadu with its nine significant partners. Its most important partners are Karnataka, Maharashtra and Andhra Pradesh. The preferred fields of cooperation with these states are:

Karnataka : *Physics* (*AFI* = 27.5%), *Chemistry* (*AFI* = 32.3%), *Engineering & Technology* (*AFI* = 22.5%), *Materials Science* (*AFI* = 48.4%), *Biomedical Research* (*AFI* = 30.4%)

Andhra : *Physics* (*AFI* = 19.2%), *Materials Science* (*AFI* = 22.6%)

Maharashtra : *Mathematics* (*AFI* = 45.4%), *Earth & Atmospheric Science* (*AFI* = 30.8%), *Clinical Medicine* (*AFI* = 20.0%)

Table 3.23
Publication Output and Interstate Cooperation in Science Fields

No. of Articles	4723
No. of Interstate Cooperation Links	566
No. of International Links	487
No. of States having at least one Link	20
Domesticity Index (%)	11.98
Centrality Index	0.300
Internationalization Index (%)	10.49

Field	*No. of Articles*	*No. of Links*	*Domesticity Index (%)*
Mathematics	79	11	13.92
Physics	1073	193	17.99
Chemistry	968	65	6.71
Biology	253	32	12.65
Earth & Atmospheric Science	90	13	14.44
Food & Agriculture	93	6	6.45
Clinical Medicine	684	70	10.23
Biomedical Research	389	23	5.91
Engineering & Technology	584	71	12.16
Materials Science	299	31	10.54
Computer Science	46	3	6.52
Total (incl. unidentified area)	4723	566	11.98

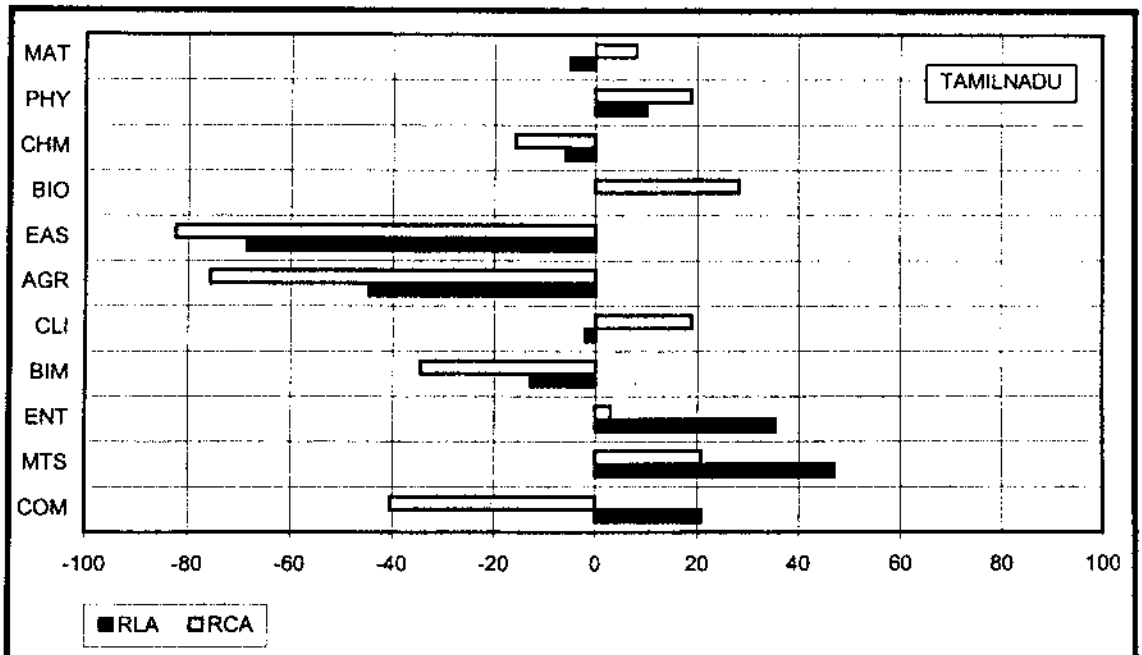

Fig. 3.41: Profiles of research and interstate cooperation

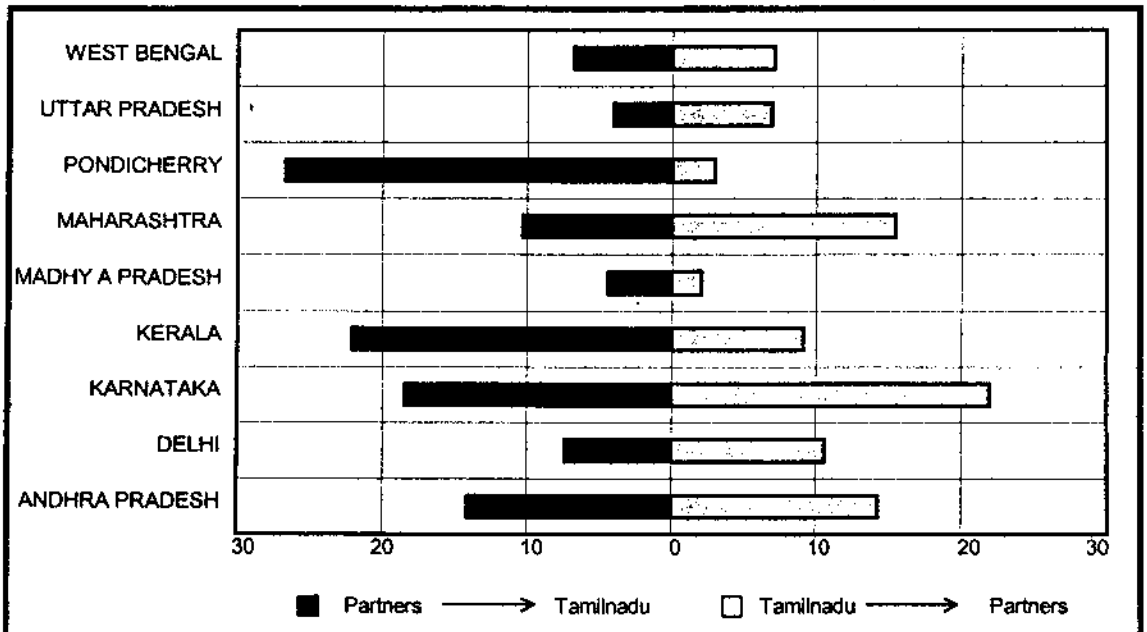

Fig. 3.42: Affinities between Tamilnadu and its significant partners

Uttar Pradesh

U.P. occupies an important position in the scientific map of India. It ranks second in terms of publication output and first in the terms of interstate cooperation links. It occupies a central position in the interstate cooperation network, which can be visualized from the span of its cooperation, extending over 26 states and high value of *Centrality Index* (0.422).

Table 3.25 presents the statistical data on publication output and cooperation links of this state during the five - year period: 1990 - 1994. Strong inter - field differences are observed in the incidence of cooperation links. The values of *Domesticity Index* vary from a low of 6.9% for *Biomedical Research* to a high of 19.65% for *Engineering & Technology*.

Research Profile

Figure 3.43 depicts the specialization profile of this state. The profile is more or less balanced, with above - average level of activity in *Biology*, *Earth & Atmospheric Sciences* and *Engineering & Technology* and below - average level of activity in *Mathematics*, *Physics*, *Materials Science* and *Computer Science*. The research activities in the remaining fields, viz. *Chemistry*, *Food & Agriculture*, *Clinical Medicine* and *Biomedical Research* are about the average.

Cooperation Profile

It can be easily seen from the cooperation profile, depicted in Figure 3.42, that *Biology* and *Engineering & Technology* receive more than average emphasis, whereas *Mathematics*, *Physics* and *Biomedical Research* receive less than average emphasis.. The remaining fields, viz. *Chemistry*, *Earth & Atmospheric Science*, *Food & Agriculture*, *Clinical Medicine* and *Materials Science* receive about the average emphasis.

Figure 3.44 depicts bidirectional affinities of UP with its twelve significant partners. It has the highest affinity towards Delhi, followed by Maharashtra. The preferred fields of cooperation with these states are:

Delhi : *Mathematics* (*AFI* = 23.1%), *Physics* (*AFI* = 25.1%), *Clinical Medicine* (*AFI* = 40.2%), *Biomedical Research* (*AFI* = 24.4%), *Computer Science* (*AFI* = 44.4%), *Materials Science* (*AFI* = 29.0%)

Maharashtra : *Mathematics* (*AFI* = 30.8%), *Physics* (*AFI* = 17.9%)

Table 3.25
Publication Output and Interstate Cooperation in Science Fields

No. of Articles	7409
No. of Interstate Cooperation Links	915
No. of International Links	840
No. of States having at least one Link	26
Domesticity Index (%)	12.35
Centrality Index	0.422
Internationalization Index (%)	11.34

Field	*No. of Articles*	*No. of Links*	*Domesticity Index (%)*
Mathematics	85	13	15.29
Physics	1274	207	16.25
Chemistry	1570	126	8.66
Biology	589	55	9.34
Earth & Atmospheric Science	464	73	15.73
Food & Agriculture	244	24	9.84
Clinical Medicine	1086	107	9.85
Biomedical Research	649	45	6.93
Engineering & Technology	908	178	19.65
Materials Science	229	42	18.34
Computer Science	57	9	15.79
Total	7409	915	12.35

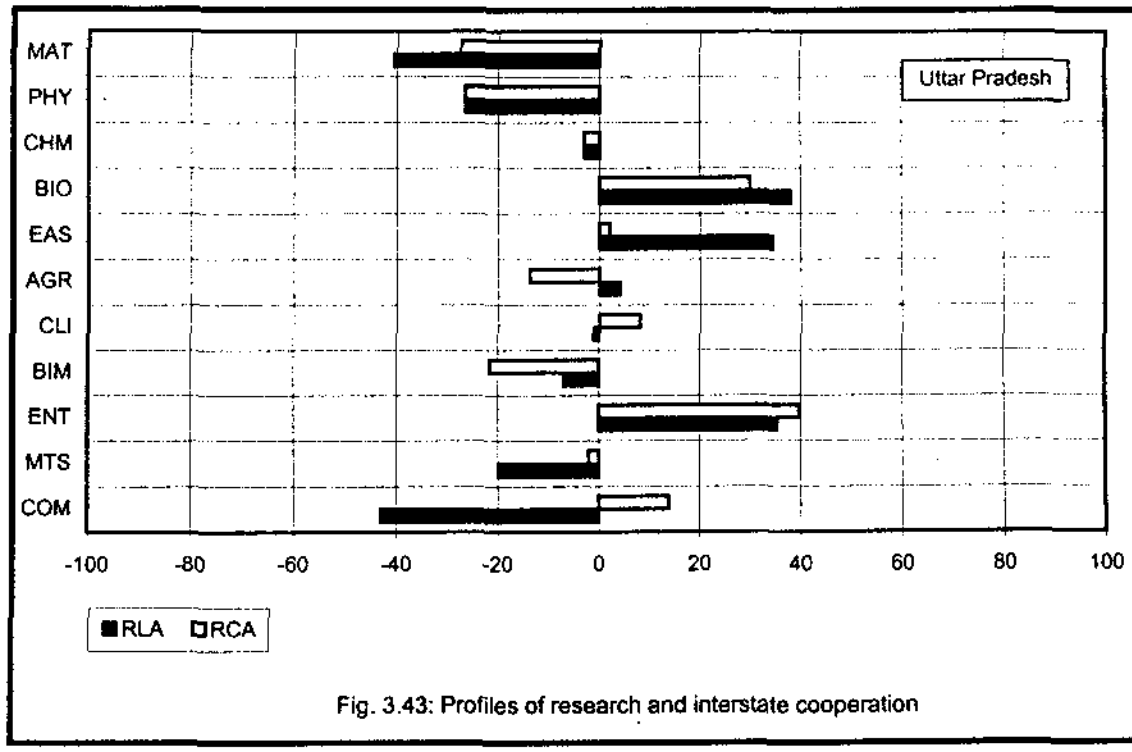

Fig. 3.43: Profiles of research and interstate cooperation

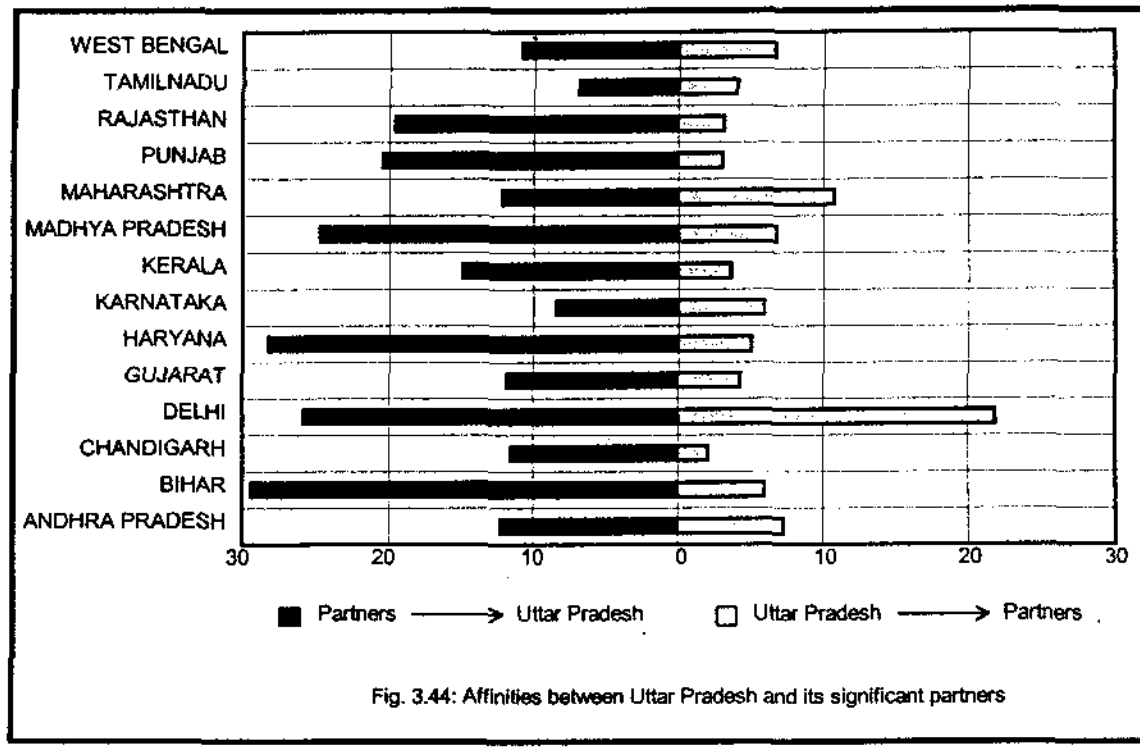

Fig. 3.44: Affinities between Uttar Pradesh and its significant partners

West Bengal

West Bengal has a pre-eminent position in the map of Indian Science. It ranks third in the output of publications, but it ranks fifth, both in the number of interstate and international cooperation links. Its cooperation network is quite wide, spanning 26 states; only one state, Sikkim, does not have any link with West Bengal. However, the value of *Bonacich Eigenvector Centrality Index* is only 0.264, which implies that it has greater orientation for links with scientifically small states.

During the five-year period: 1990-1994, this state contributed 6370 articles to the *SCI*-covered journals, involving 575 interstate and 509 international cooperation links.

Table 3.26 presents the data on publication output and interstate cooperation ties of this state during these five years. The variations in cooperation links in different fields may be visualized from the values of *Domesticity Index*, which range from a low of 2.3% for *Biomedical Research* to a high of 22.8% for *Earth & Atmospheric Science*. *Biomedical Research* and *Chemistry* seem to be isolated; less than 5% of publications in each of these fields involve cooperation with other states.

Research Profile

Figure 3.45 depicts the specialization profile of this state which is oriented towards *Mathematics*, *Physics*, *Materials Science* and *Computer Science*. *Biology*, *Earth & Atmospheric Science*, *Food & Agriculture* and *Clinical Medicine* receive much less emphasis in the research agenda of this state. *Chemistry*, *Biomedical Research* and *Engineering & Technology* have about average levels of research activity.

Cooperation Profile

Figure 3.45 depicts the cooperation profile of this state, which has remarkable similarity to its research specialization profile. The profile shows that *Mathematics*,

Physics and *Computer Science* receive greater emphasis for cooperation, whereas *Chemistry*, *Clinical Medicine* and *Biomedical Research* receive much less emphasis.

Figure 3.46 shows bidirectional affinities of this state with its 13 significant partners, but none of these states dominates its affinity profile.

Table 3.26
Publication Output and Interstate Cooperation in Science Fields

No. of Articles	6370
No. of Interstate Cooperation Links	575
No. of International Links	509
No. of States having at least one Link	26
Domesticity Index (%)	9.03
Centrality Index	0.264
Internationalization Index (%)	7.99

Field	*No. of Articles*	*No. of Links*	*Domesticity Index (%)*
Mathematics	143	26	13.99
Physics	2075	226	10.89
Chemistry	1400	63	4.50
Biology	239	23	9.62
Earth & Atmospheric Science	197	45	22.84
Food & Agriculture	116	20	17.24
Clinical Medicine	452	31	6.86
Biomedical Research	693	16	2.31
Engineering & Technology	529	86	16.26
Materials Science	317	29	9.15
Computer Science	123	11	8.94
Total	6370	575	9.03

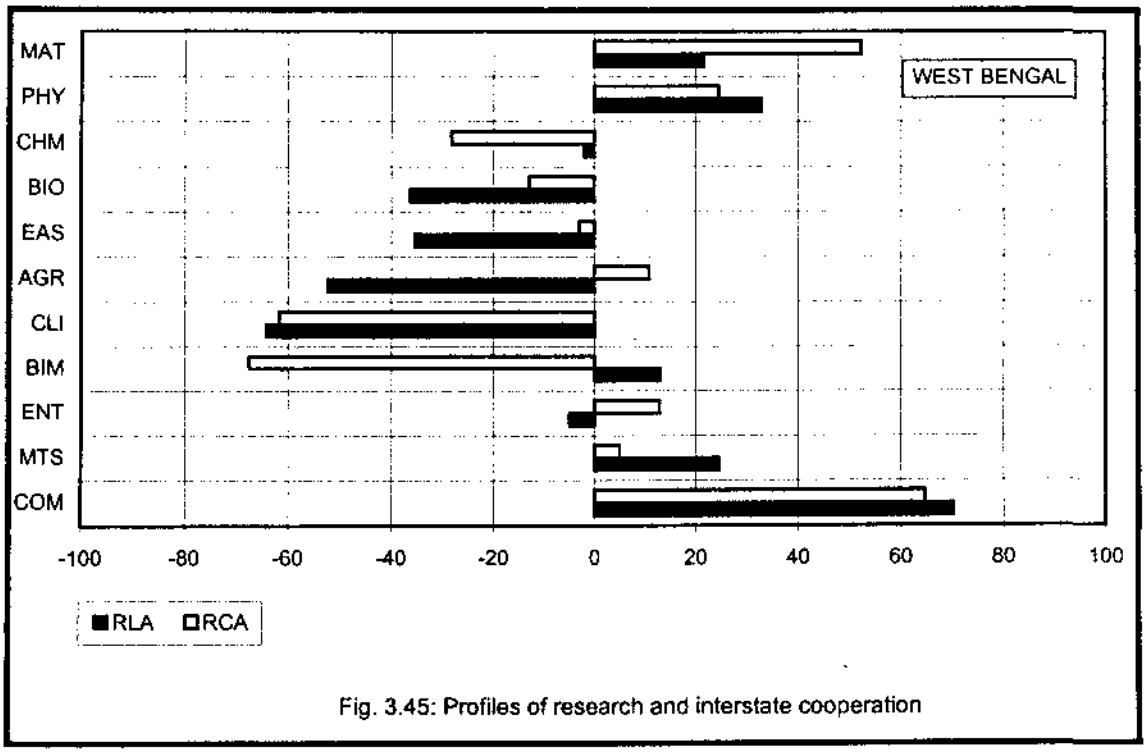

Fig. 3.45: Profiles of research and interstate cooperation

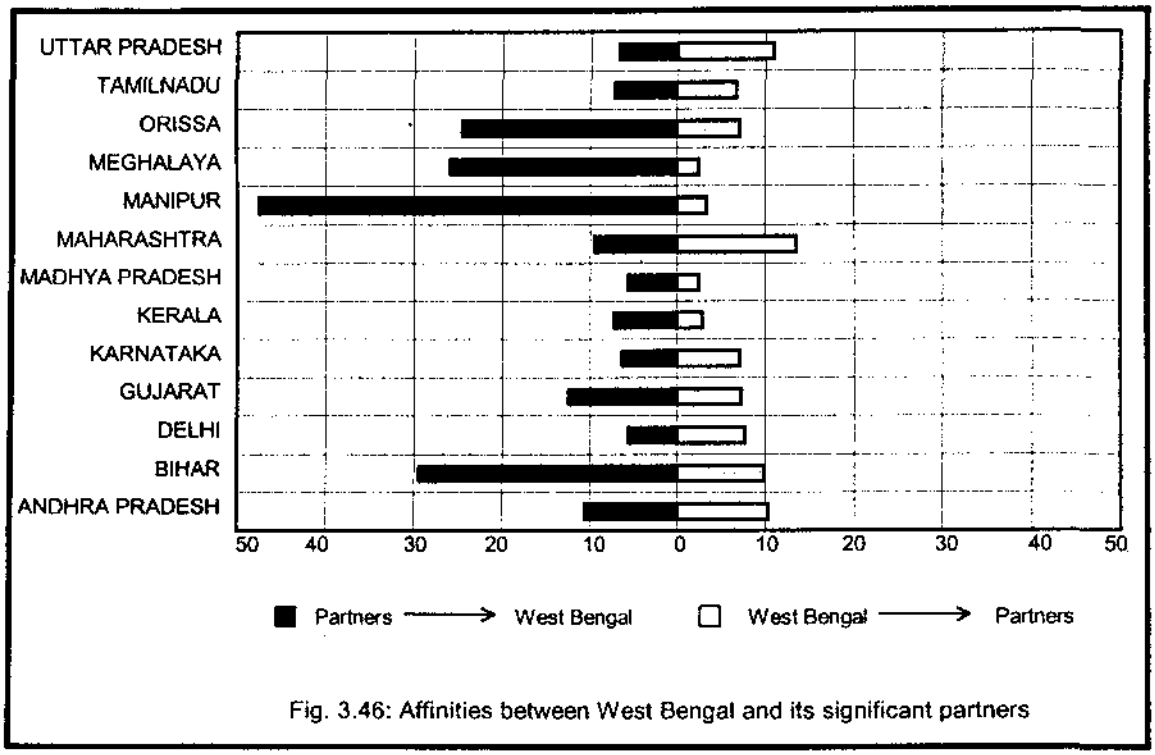

Fig. 3.46: Affinities between West Bengal and its significant partners

4 Structural Analysis

In Chapter 3, we had examined:

(i) The fields of strength and weakness of each state, using the bibliometric indicator – Revealed Publication Advantage (*RLA*).

(ii) The fields of emphasis or de-emphasis of each state for interstate cooperation, using the bibliometric indicator – Revealed Cooperation Advantage (*RCA*).

(iii) The strength of mutual relations among the states, using *Affinity Index*.

These univariate analyses, based on state – by – state and field – by – field comparisons, are quite revealing but also time-consuming. They do not reveal the structure of the multidimensional data.

In this chapter, we would analyze:

(i) The structure of the system of multivariate relationships between states and fields of research performance.

(ii) The structure of the system of multivariate relationships between states and fields of interstate cooperation.

(iii) The structure of mutual cooperation among the states.

The first two analyses would be performed through Correspondence Analysis, whereas the third analysis would be performed through Network Analysis.

Structure of Research Output

Tables 3.2 (page 33) and 3.3 (page 38) present respectively the distributions of articles and coauthorships links in 28 states and 11 science fields. However, these data sets do not convey much information for the following reasons:

(i) The sheer size of such data sets blurs the overall structure and their hidden features.

(ii) The raw counts of articles and coauthorship links are confounded by the size of the states and science fields.

Moreover, these data sets have inbuilt redundancy due to the attribution of coauthored articles to the state of each author. 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 science fields. It may be re-called 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 – eleven science 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.

According to Engelsman & van Raan (1994) a cartographic approach to structural analysis, not only reformats the data into a specific graphical representation (i.e. maps), it also accomplishes *data reduction*, while retaining the essential information. Correspondence analysis is a high-performance cartographic technique that minimizes the effect of redundancy and filters out noise in the data.

Correspondence Analysis

Correspondence Analysis is a *pattern recognition* technique, whereby it is possible to compare the patterns of relationships between the rows and columns of a contingency

table, for example the patterns of cooperation links of various states in different fields or subfields (normalized profiles). The technique filters out noise and highlights the most legitimate correlations among the variables (i.e. states and fields). These correlations can be best seen on biplots of factorial axes that describe ever – decreasing proportions of the total variance (i.e. information content) of the multidimensional system of relationship between the variables under study. The higher – order map, spanned by the first two factorial axes, reveals the strongest correlations among the variables. The lower – order maps reveal weaker, but equally meaningful correlations.

Correspondence Analysis generates factorial biplots and computes the eigen values, which indicate the variance in the multdimensional system explained by different factorial axes. It also computes absolute contributions (Ctr) and relative contributions ($Cos^2\phi$) of row and column elements of the data matrix, which help in the interpretation of the results of correspondence analysis.

We have devised an *Infographic Map*, in which the results of different factorial maps can be condensed to provide an overview or summary of the results of Correspondence Analysis.

The structure of the multidimensional system of relationships between twenty four states and eleven science fields in the space of research output was analyzed through correspondence analysis, using the computer program SimCA[1]. Four states (Arunachal, Andaman, Mizoram, Sikkim) which did not meet the χ^2 – criterion[2] for the computation of activity index were excluded from the analysis. The field of *Computer Science,* which had few links, was treated as 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 value of the Chi – square statistic (χ^2 = 11563; df = 207) computed by the program is highly significant, which provides strong evidence that the association between the two sets of variables (states, fields) is not random. Moreover, eigen values issued by the program indicate that the total inertia ($\Sigma\lambda i$ = 0.218049) is sufficiently large, suggesting variations in the amplitudes of profiles of states and fields. The results of correspondence analysis are summarized in Tables 4.1 and 4.2.

The first four axes ϕ_1 – ϕ_4, indicating about 87% 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 59% of the total variance, represent the essential features of the system; the third and fourth axes provide complementary data for further analysis and elaboration.

Figure 4.1 represents the two – dimensional factorial map constituted by ϕ_1 and ϕ_2 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* is represented on the first and fourth axes.

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, J&K.

Cluster 2: Andhra, Assam, Orissa and Meghalaya

Table 4.1
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 (λ_1 = 0.074517, τ_1 = 34.17%)	
Fields	Clinical Medicine (725)	—
States	Chandigarh (373), Delhi (271), Pondicherry (79)	Andhra (86)
	Axis 2 (λ_2 = 0.054051, τ_2 = 24.79%)	
Fields	Biology (127), Earth & Atmospheric Science (467)	Physics (229)
States	Goa (422), Haryana (66), Uttar Pradesh (64) Punjab (41)	Maharashtra (70), West Bengal (140)
	Axis 3 (λ_3 = 0.038806, τ_3 = 17.80%)	
Fields	Earth & Atmospheric Science (341)	Agriculture (535)
States	Goa (270), Maharashtra (57), Gujarat (58)	Haryana (226), Himachal Pradesh (76), Punjab (232)
	Axis 4 (λ_4 = 0.038806, τ_4 = 17.80%)	
Fields	Engineering & Technology (531), Materials (136)	Chemistry (275)
States	Bihar (266), Karnataka (79), Tamilnadu (105)	Gujarat (142), Rajasthan (44)

* Values are in permills

Table 4.2
Contributions of explained points to the composition of factorial axes $(\cos^2\phi)^*$ (Research output).

Cloud	*Explicative points with positive coordinates*	*Explicative points with negative coordinates*
	Axis 1 (λ_1 = 0.074517, τ_1 = 34.17%)	
Subfields	Clinical Medicine (952)	Chemistry (388)
States	Chandigarh (930), Delhi (922), J&K (270), Pondicherry (896)	Andhra (590), Assam (471), Orissa (333) Meghalaya (285)
	Axis 2 (λ_2 = 0.054051, τ_2 = 24.79%)	
Subfields	Agriculture (247), Biology (481), Earth & Atmospheric Science (567)	Physics (621), Mathematics (254), Computers (361)
States	Goa (607), Haryana (261), J&K (436), Kerala (300), Uttar Pradesh (453)	Karnataka (338), Maharashtra (434), Tamilnadu (309), West Bengal (553)
	Axis 3 (λ_3 = 0.038806, τ_3 = 17.80%)	
Subfields	Agriculture (682)	Earth & Atmospheric Science (298)
States	Haryana (643), Himachal Pradesh (588), Punjab (689)	Gujarat (271), Goa (279)
	Axis 4 (λ_4 = 0.038806, τ_4 = 17.80%)	
Fields	Engineering & Technology (745), Materials (387)	Chemistry (336)
States	Bihar (801), Karnataka (260), Tamilnadu (454)	Assam (300), Gujarat (368), Madhya Pradesh (392), Rajasthan (271)

* Values are in permills

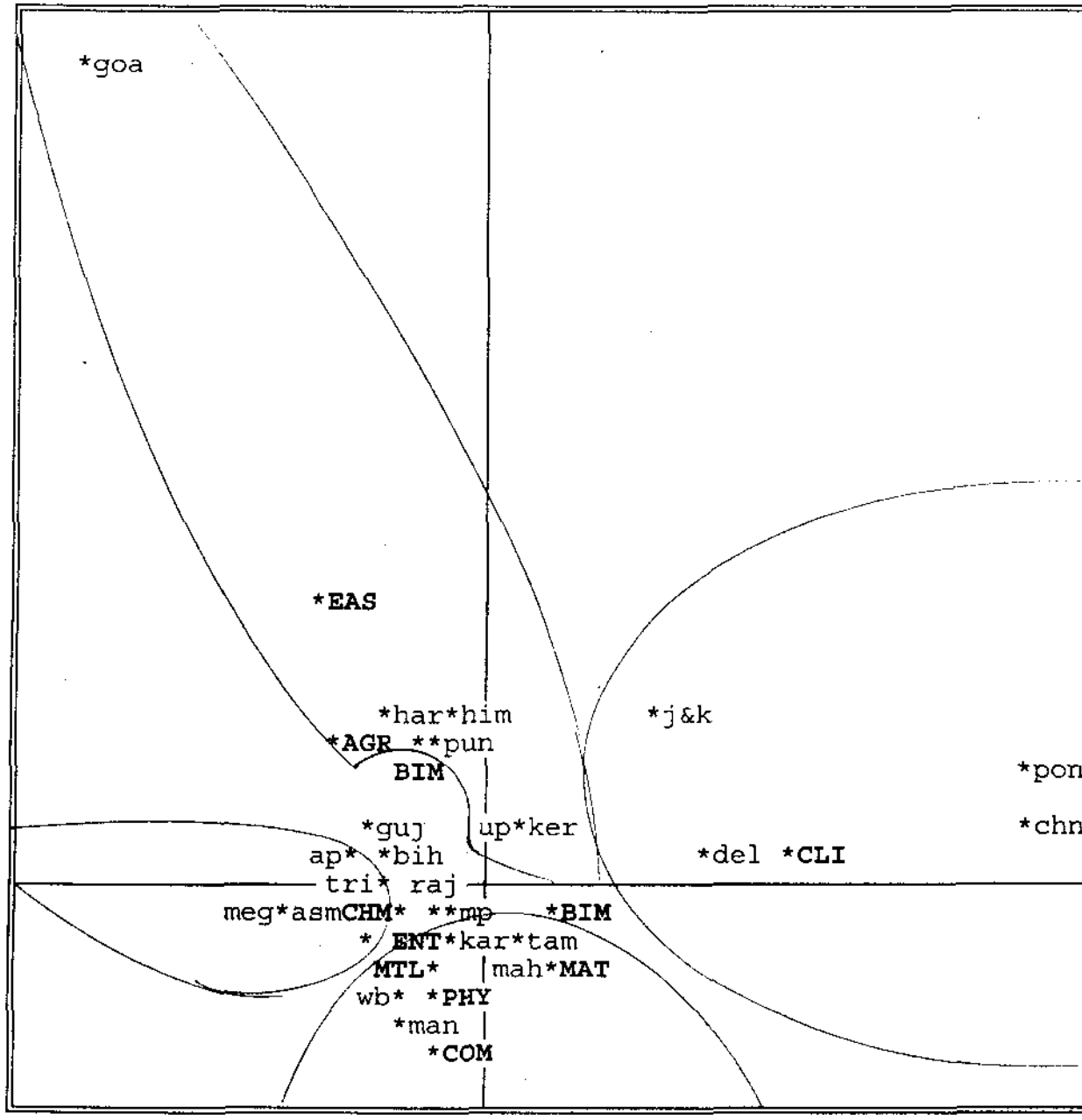

Fig. 4.1: Correspondence analysis of publication output (ϕ_1, ϕ_2)

Horizontal axis is dimension 1 with inertia = 0.0745 (34.2%)
Vertical axis is dimension 2 with inertia = 0.0541 (24.8%)

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. On the cloud of fields this factor is characterized by the polarity between *Earth & Atmospheric Science*, *Agriculture* and *Biology* on the one hand and *Physics*, *Mathematics* and *Computer Science* 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, J&K and Kerala.
Cluster 2: Karnataka, Maharashtra, West Bengal and Tamilnadu.

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

Factor ϕ_3: This factorial axis accounts for 17.80% of the total variance in the multidimensional system. Figure 4.2 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 & Atmospheric 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.

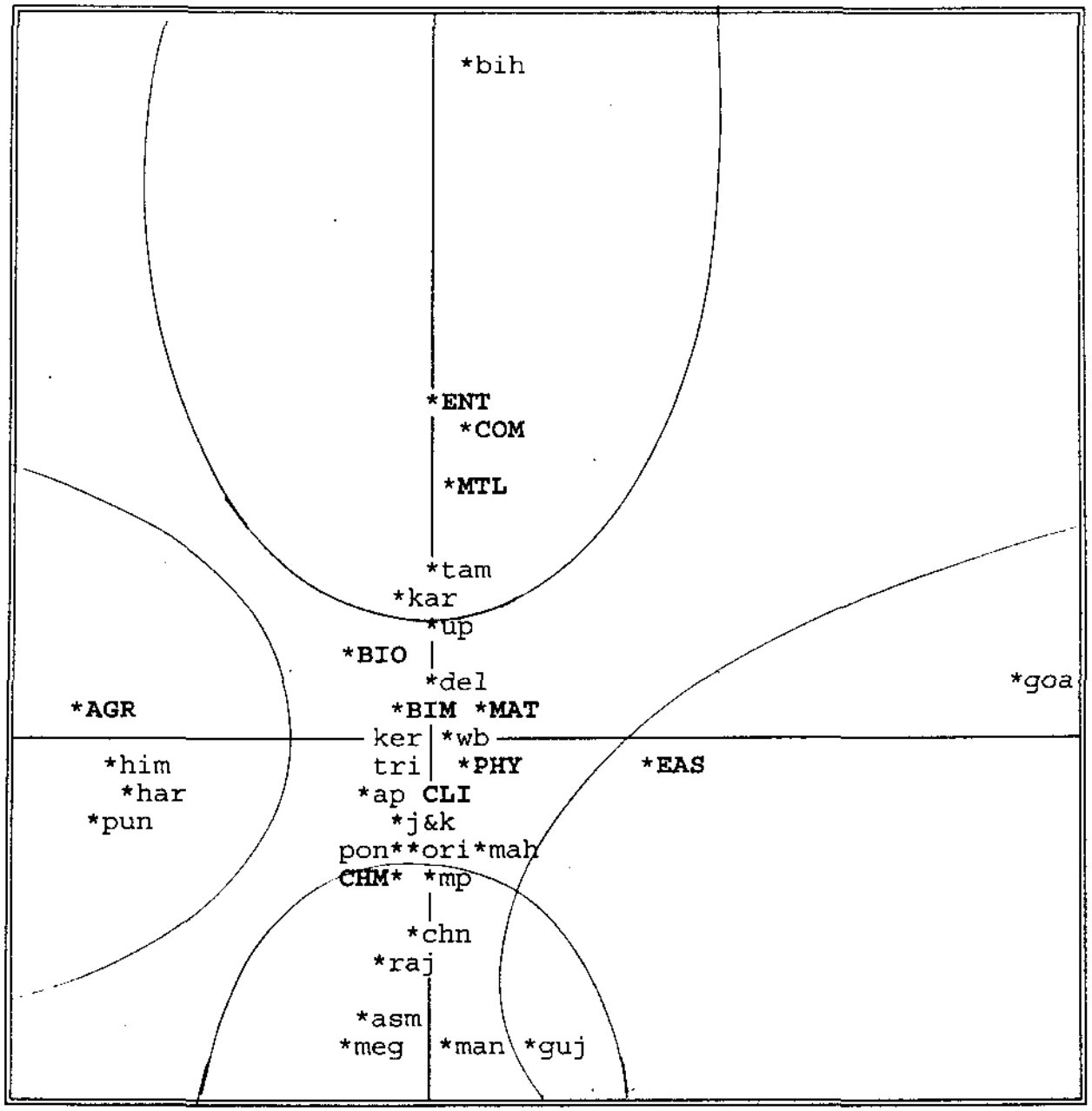

Fig. 4.2: Correspondence analysis of publication output (ϕ_3, ϕ_4)

Horizontal axis is dimension 3 with inertia = 0.0388 (17.8%)
Vertical axis is dimension 4 with inertia = 0.0214 (9.8%)

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 & Atmospheric Science*.

Factor ϕ_4: This factorial axis, accounting for 9.8% of the total variance, is characterized by the polarity between *Engineering & Technology* and *Materials* on the one hand and *Chemistry* on the other.

The states correlated to this axis can be classified into two clusters, depending upon the signs of their projection coordinates:

Cluster 1: Bihar, Karnataka and Tamilnadu.
Cluster 2: Assam, Gujarat, Madhya Pradesh and Rajasthan.

Cluster 1 states are correlated to *Engineering & Technology* and *Materials*, whereas *Cluster* 2 states are correlated to *Chemistry*.

Structure of Interstate Cooperation

The structure of the multidimensional system of relationships between twenty four states and eleven fields in the space of interstate cooperation was analyzed through correspondence analysis. Four states, viz. Andaman, Arunachal, Mizoram and Sikkim were excluded from the analysis. The field of *Computer Science*, in which there were few interstate links, was treated as supplementary variable.

The value of the Chi - square statistic (χ^2 = 1349, df = 207) is highly significant, which provides strong evidence that the association between states and fields is not random. Eigen values issued by the program indicate that the total inertia ($\Sigma\lambda i$ = 0.205901) is sufficiently large, implying variations in the amplitudes of profiles of states and fields.

The first four factorial axes, summing up about 78% of the total variance, provide the most parsimonious representation of the multidimensional data. The two – dimensional configuration spanned by ϕ_1 and ϕ_2 axes accounts for about 50% of the total variance and therefore represents the essential features of the multidimensional system. The third and fourth factorial axes provide complementary data for further analysis and elaboration.

The results of correspondence analysis are summarized in Tables 4.3 and 4.4. Figure 4.3 represents the two – dimensional factorial map spanned by ϕ_1 and ϕ_2 axes.

Factor ϕ_1: This factorial axis, accounting for 26.3% of the total variance is the most important element of the multidimensional system.

On the cloud of fields, this axis is characterized by the polarity between *Engineering & Technology* and *Materials* on the one hand and *Clinical Medicine* and *Biomedicine* on the other. *Engineering & Technology* and *Materials* are projected with positive coordinates and *Clinical Medicine* and *Biomedicine* are projected with negative coordinates.

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

Cluster 1: Bihar and West Bengal.
Cluster 2: Chandigarh, Delhi, Himachal, Jammu & Kashmir and Pondicherry.

Cluster 1 states are projected on this axis with positive coordinates and are therefore correlated to *Engineering & Technology* and *Materials*. *Cluster* 2 states are projected on this axis with negative coordinates, and are therefore correlated to *Clinical Medicine* and *Biomedicine*. These states have preference for cooperation in these two fields.

Factor ϕ_2: This factorial axis accounts for about 23.1% of the total variance in the multidimensional system.

Table 4.3
Contributions of explicative points to the composition of factorial axes (Ctr)* (Interstate links)

Cloud	*Explicative points with positive coordinates*	*Explicative points with negative coordinates*
	Axis 1 (λ_1 = .054189, τ_1 = 26.32%)	
Fields	Engineering & Technology (244)	Clinical Medicine (434), Biomedical Research (114)
States	Bihar (147)	Haryana (613)
	Axis 2 (λ_2 = .047528, τ_2 = 23.08%)	
Fields	Earth & Atmospheric Science (252) Engineering & Technology (120)	Physics (466)
States	Andhra (73), Bihar (102), Goa (112), Kerala (76), UP (91)	Madhya Pradesh (55), Maharashtra (216), Orissa (56), Tamilnadu (55)
	Axis 3 (λ_3 = .037456, τ_3 = 18.19%)	
Fields	Engineering & Technology (284) Clinical Medicine (110)	Earth & Atmospheric Science (420)
States	Bihar (173), Tamilnadu (53), UP (70)	Goa (249), Gujarat (289)
	Axis 4 (λ_4 = .021482, τ_4 = 10.43%)	
Fields	Agriculture (579)	Clinical Medicine (170
States	Haryana (77), Punjab (456)	Delhi (51), Goa (115), Pondicherry (71)

* Values are in permills

Table 4.4
Contributions of explained points to the eccentricities of factorial axes $(\cos^2\phi)^*$ (Interstate links)

Cloud	*Explained points with positive coordinates*	*Explained points with negative coordinates*
	Axis 1 (λ_1 = .054189, τ_1 = 26.32%)	
Fields	Engineering & Technology (435) Materials Science (296)	Clinical Medicine (705) Biomedical Research (435)
States	Bihar (390), West Bengal (510)	Chandigarh (678), Delhi (639), Himachal (598), J&K (428), Pondicherry (672)
	Axis 2 (λ_2 = .047528, τ_2 = 23.08%)	
Fields	Earth & Atmospheric Science (373)	Mathematics (309), *Physics (806)*
States	Andhra (474), Assam (352), Bihar (238) Goa (78), Kerala (420), UP (490)	Madhya Pradesh (779), Maharashtra (849), Orissa (518), Tamilnadu (366), Tripura (480)
	Axis 3 (λ_3 = .037456, τ_3 = 18.19%)	
Fields	Engineering & Technology (350) Materials Science (386)	Earth & Atmospheric Science (490)
States	Bihar (317), Tamilnadu (253), UP (295)	Goa (488), Gujarat (752)
	Axis 4 (λ_4 = .021482, τ_4 = 10.43%)	
Fields	Agriculture (566)	—
States	Haryana (468), Punjab (644)	

* Values are in permills

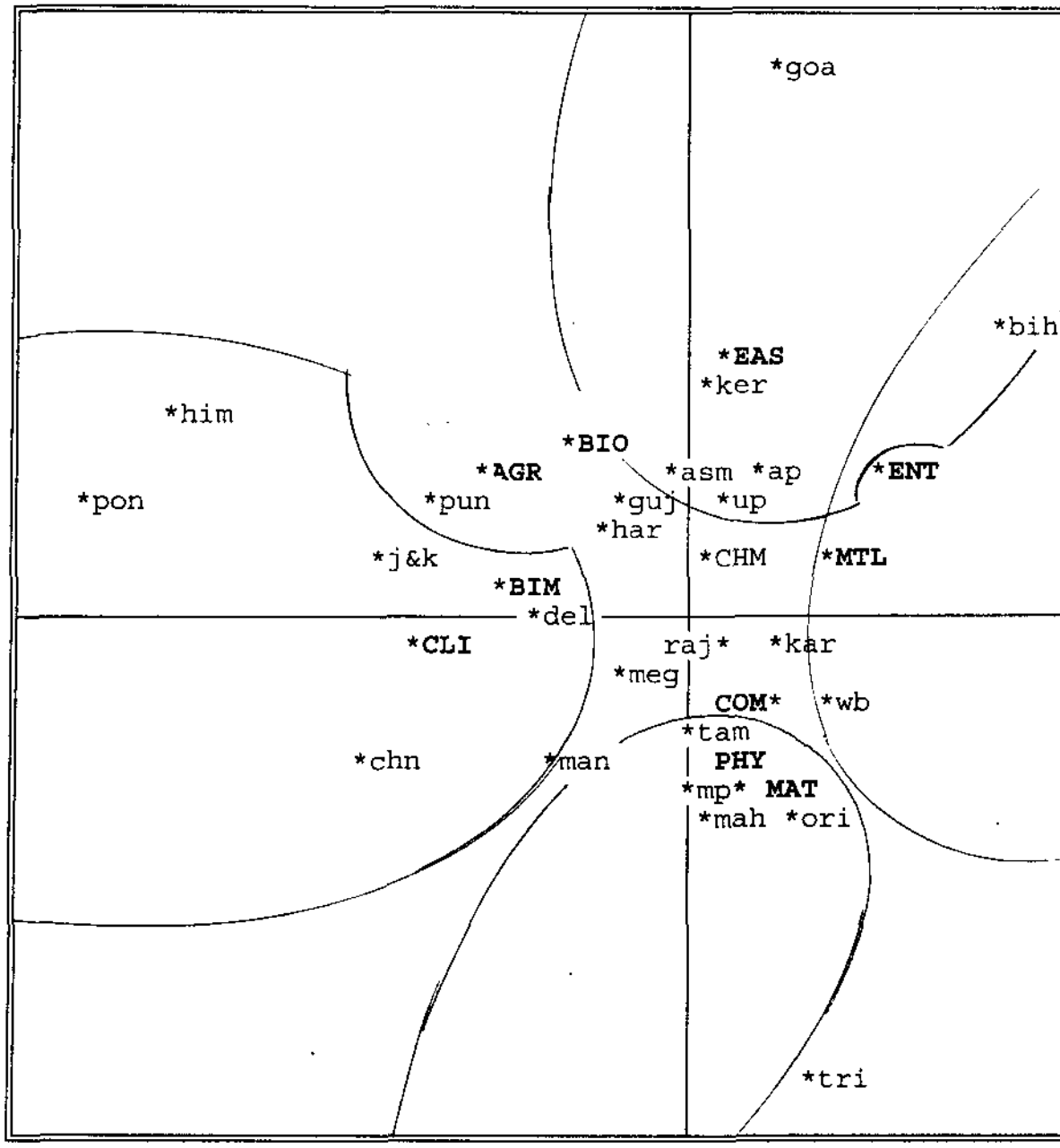

Fig. 4.3: Correspondence analysis of interstate cooperation (ϕ_1, ϕ_2)

Horizontal axis is dimension 1 with inertia = 0.0542 (26.3%)
Vertical axis is dimension 2 with inertia = 0.0475 (23.1%)

On the cloud of fields, this factor is characterized by the polarity between *Earth & Atmospheric Science* on the one hand and *Mathematics* and *Physics* on the other.

On the cloud of states, this axis is characterized by the polarity between Andhra, Bihar, Assam, Goa, Kerala and UP on the one hand and Madhya Pradesh, Maharashtra, Orissa, Tamilnadu and Tripura on the other. The cooperation profiles of Andhra, Bihar, Assam, Goa, Kerala and UP are prominent in *Earth & Atmospheric Science*, whereas those of Madhya Pradesh, Maharashtra, Orissa, Tamilnadu and Tripura are prominent in *Mathematics / Physics*.

Factor ϕ_3: The third factorial axis accounts for about 18.2% of the total variance in the multidimensional system. Figure 4.4 presents the two - dimensional factorial map spanned by ϕ_3 and ϕ_4 axes.

On the cloud of fields this axis is characterized by the polarity between *Engineering & Technology* and *Materials* on the one hand and *Earth & Atmospheric Science* on the other. These two fields are projected with positive coordinates. *Earth & Atmospheric Science* is projected with negative coordinate.

On the cloud of states, this axis is characterized by the opposition between Gujarat and Goa (projected with negative coordinates) on the one hand and Tamilnadu, UP and Bihar (projected with positive coordinates) on the other. Tamilnadu, UP and Bihar cooperate preferentially in *Engineering & Technology /Materials*, whereas Goa and Gujarat cooperate preferentially in *Earth & Atmospheric Science*.

Factor ϕ_4: This axis accounts for 10.4% of the total variance

It is a unipolar factor, dominated by *Agriculture*. This field is projected on this axis with positive coordinates.

Haryana and Punjab, which are correlated to this axis, are projected with positive coordinates. These states have preference for cooperation in *Agriculture*.

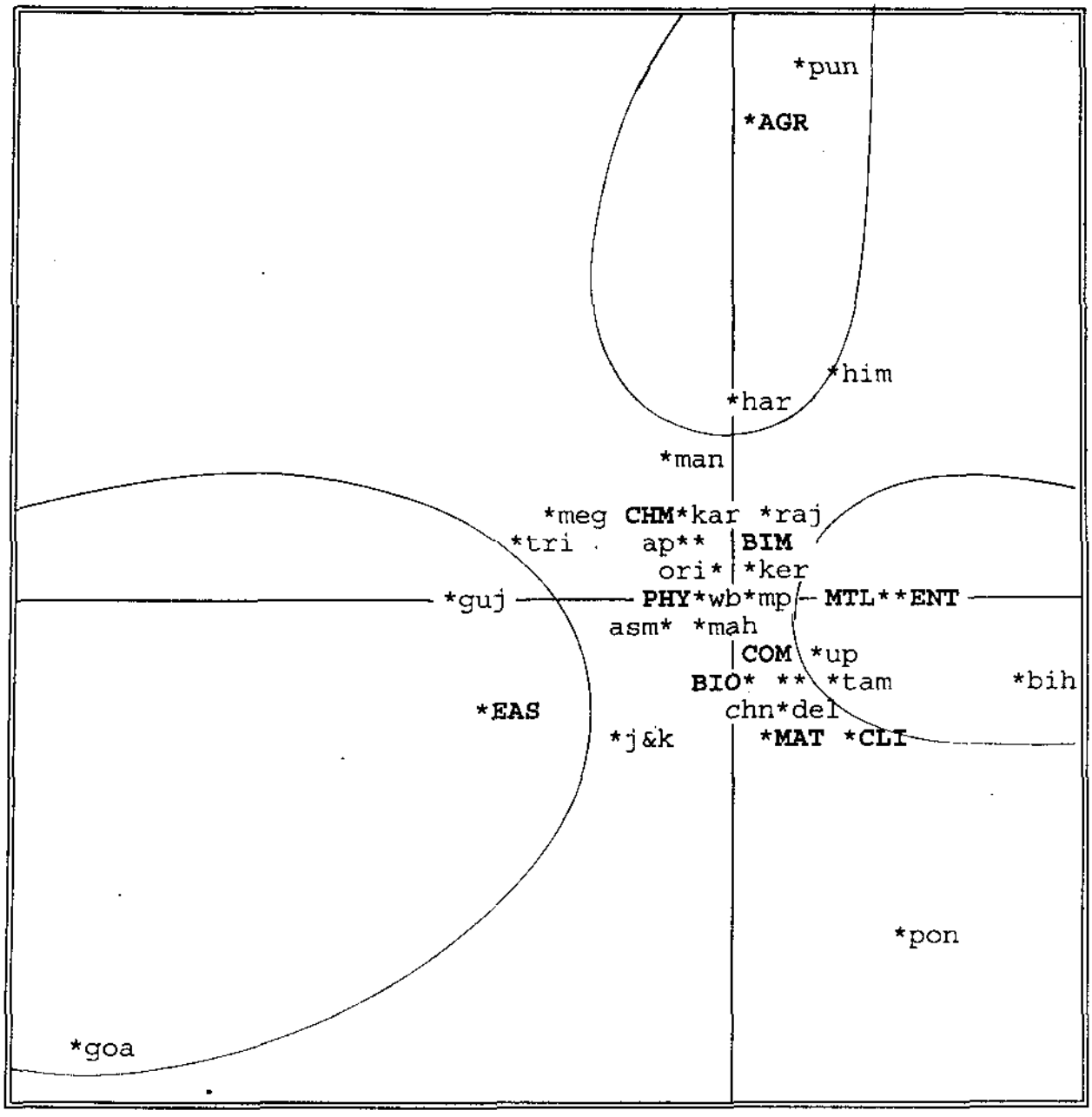

Fig. 4.4: Correspondence analysis of interstate cooperation (ϕ_3, ϕ_4)

Horizontal axis is dimension 3 with inertia = 0.0375 (18.2%)
Vertical axis is dimension 4 with inertia = 0.0215 (10.4%)

The complex structures of relationships of 24 states with eleven science 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 4.5 and 4.6). 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 states and fields are located at different points, and inter – point distances have certain meaning. In the *Infographic Map*, only those states and fields are displayed, which are correlated to the significant factorial axes. Both states and fields are located at the poles of the factorial axes and inter – point distances have no meaning!

The states and fields located at a given pole of a factorial axis are associated. This means that the states have stronger preference for publication (or cooperation) in the fields located at the proximate pole. These states 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.

Comparisons of Structures of Research Output and Cooperation

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

1. Total inertia of the two configurations is about the same. This means that the eccentricities of the profiles of research output and interstate cooperation are about the same. However, this does not mean that two profiles are similar.
2. There are also differences in the composition of factorial axes on both the clouds (i.e. fields and states).
3. The prominence of fields of research and interstate cooperation do not always match with each other.

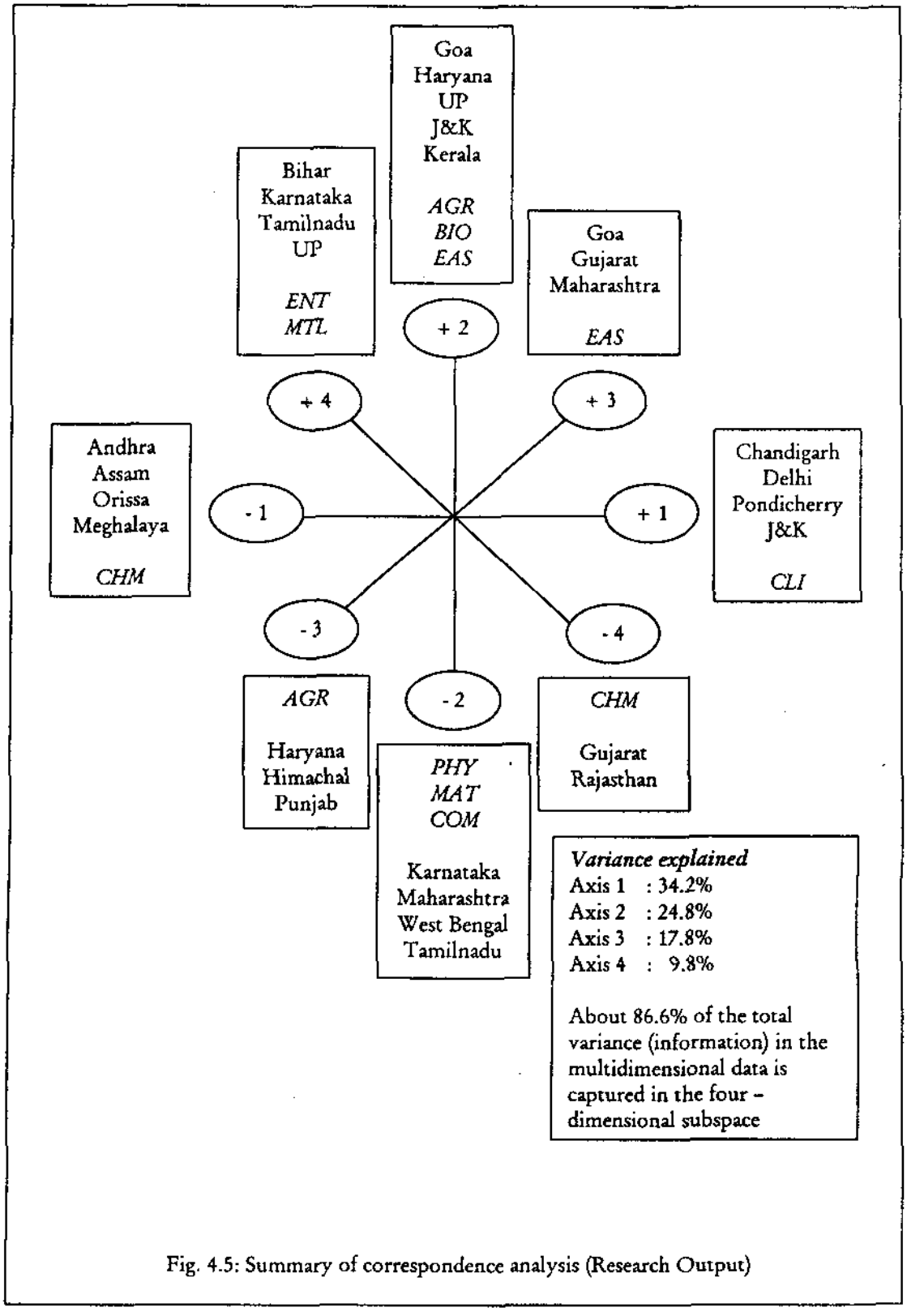

Fig. 4.5: Summary of correspondence analysis (Research Output)

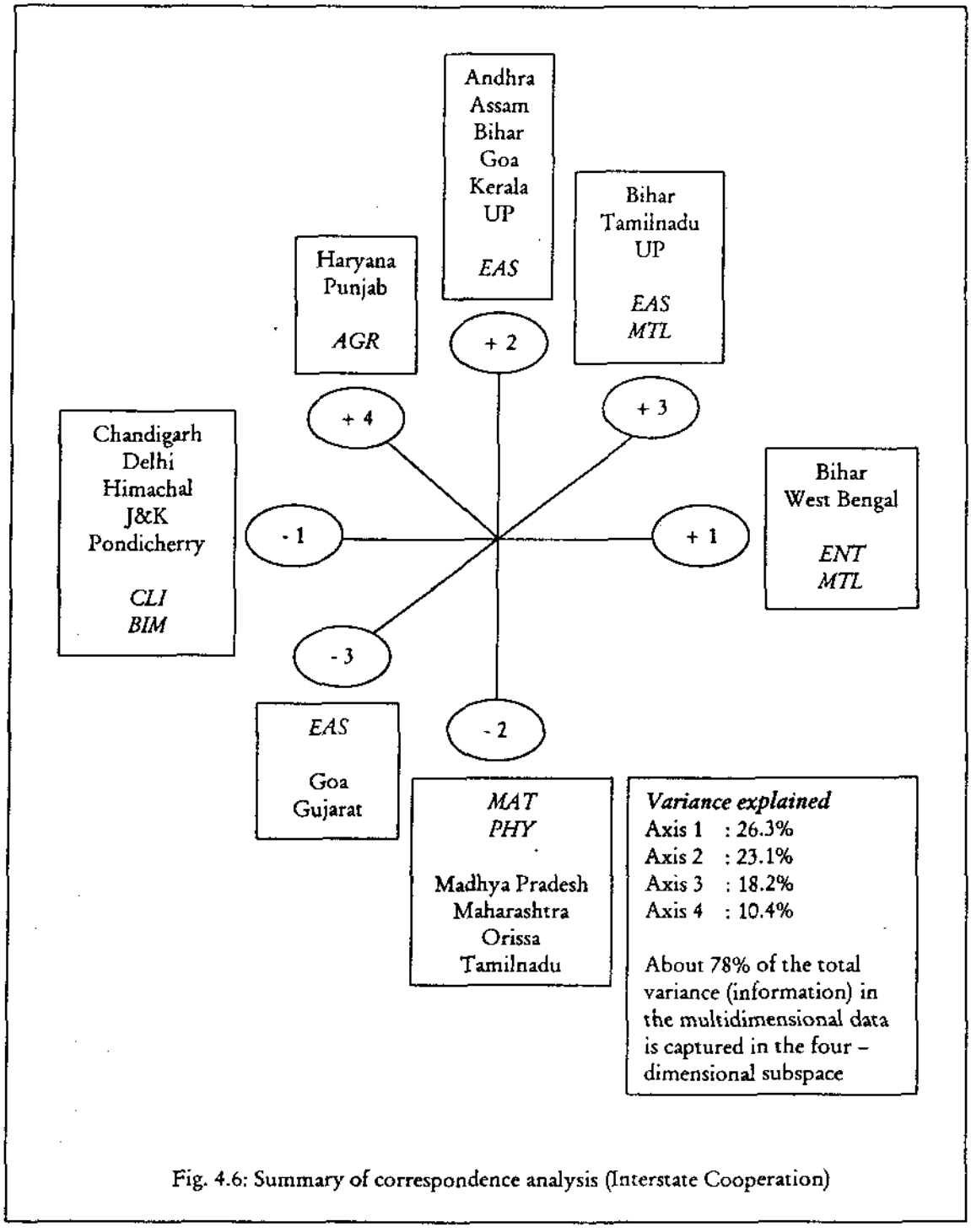

Fig. 4.6: Summary of correspondence analysis (Interstate Cooperation)

These results imply that research cooperation between states is not necessarily influenced by their research profiles.

To examine the differences in the structures of research output and interstate cooperation links rather systematically, the following statistical procedures were adopted:

(i) Matching of the two configurations using Cliff's algorithm[3]. This procedure provides a global index of concordance between the configurations.

(ii) Introduction of the normalized profiles of interstate cooperation into the factorial map of research output 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.

Matching of Configurations

The matrices of projection coordinates of the row and column points on the first four (significant) factorial axes (24 × 4) for the two configurations were submitted to the computer program FMATCH[4], 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 $\mathcal{H}$ – space and $\mathcal{Y}$ – 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 eigenroots and eigenvectors 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:

$$GFI = 0.610$$

which indicates that the fit between the two configurations is 'unsatisfactory'.

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 4.7 and 4.8) – one for (Andhra, Assam, Bihar, Chandigarh, Delhi, Goa, Himachal, Jammu & Kashmir, Karnataka, Kerala, Maharashtra and Manipur) and the other for (Gujarat, Haryana, Madhya Pradesh, Meghalaya, Orissa, Pondicherry, Punjab, Rajasthan, Tamilnadu, Tripura, UP and West Bengal).

In these maps, *lower case* letters representing the states pertain to research output and the *upper case* letters representing the states pertain to cooperation links.

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 some other states the distance is considerable. Lines have been drawn between the corresponding points of a state if the distance is 'considerable'.

For interpretation of these factorial maps, it is necessary to recall that the first factorial axis represents the polarity between *Clinical Medicine* (positive coordinate) and *Chemistry* (negative coordinate), whereas the second factorial axis represents the polarity between *Agriculture*, *Biology* and *Earth & Atmospheric Science* (positive coordinates) and *Physics*, *Mathematics* and *Computer Science* (negative coordinates).

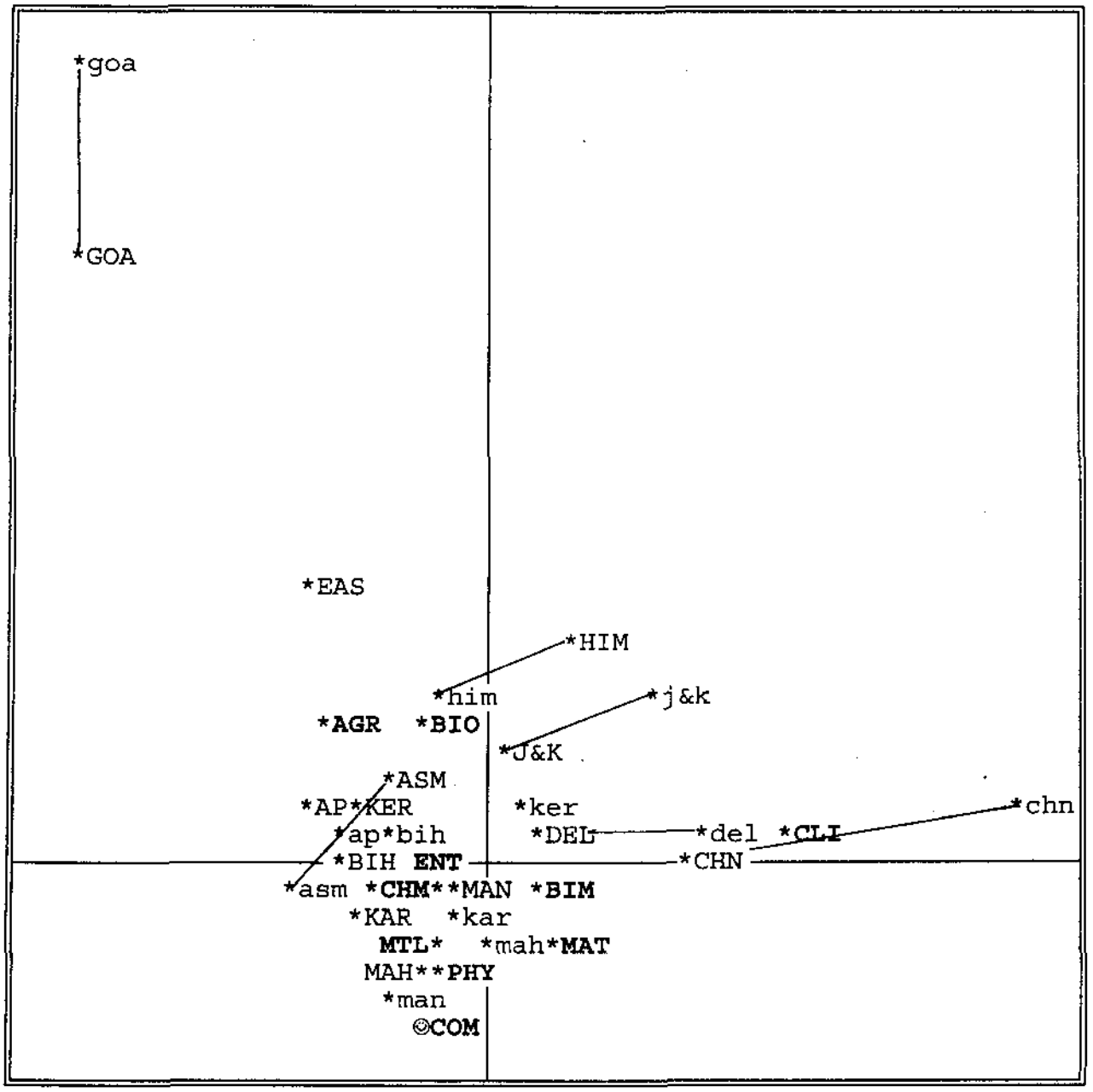

Fig. 4.7: Corresponding analysis map showing deviations between research output and interstate cooperation

State points for research output : lower case letters
State points for interstate cooperation : upper case letters
©: Not represented in the map

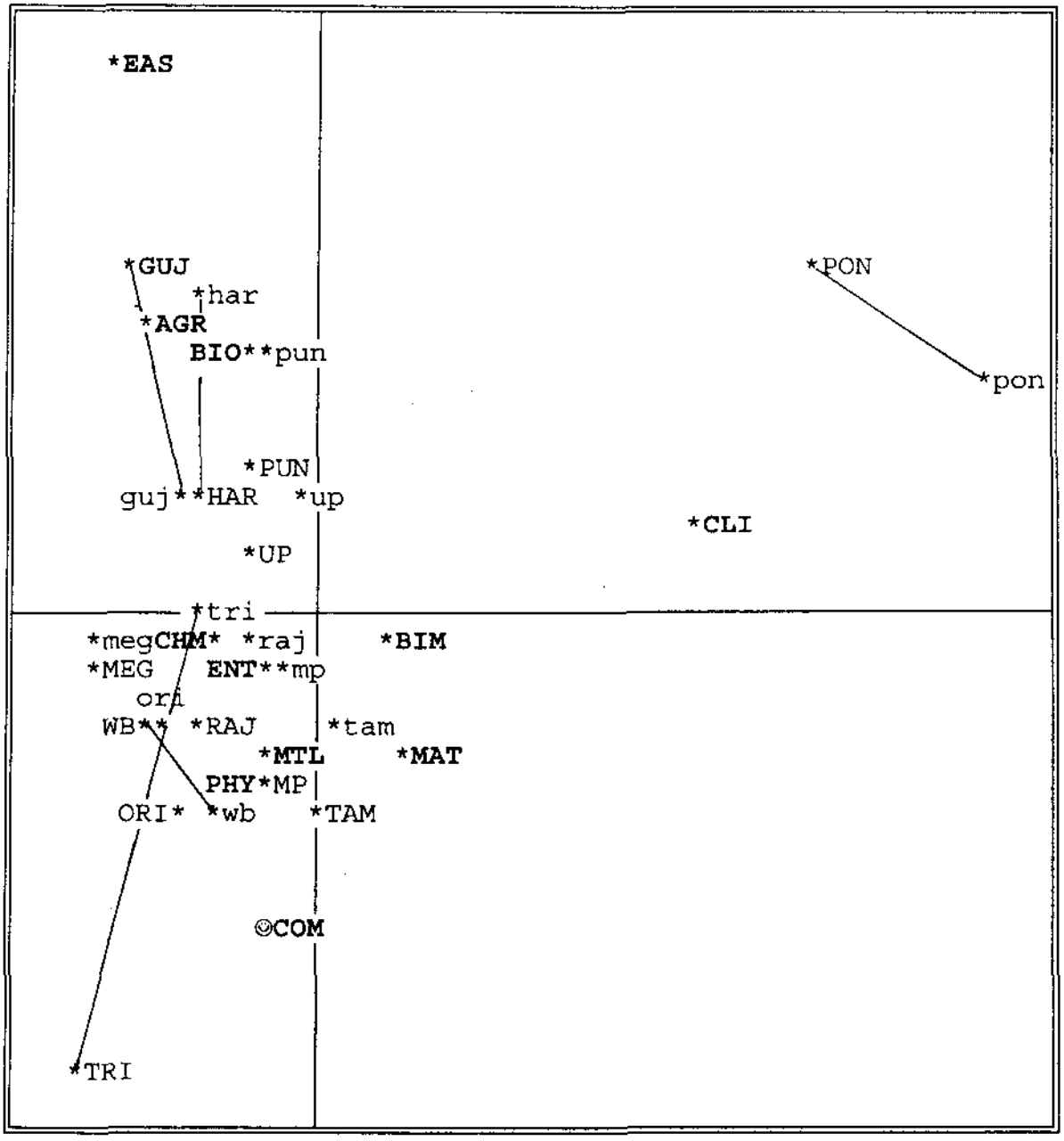

Fig. 4.8: Corresponding analysis map showing deviations between research output and interstate cooperation

State points for research output : lower case letters
State points for interstate cooperation : upper case letters
©: Not represented in the map

Considerable distances in the corresponding points of the following states are observed:

Assam	:	Correlated to *Chemistry* for research but not for interstate cooperation.
Chandigarh	:	Correlated to *Clinical Medicine* for research as well as for interstate cooperation, but the level of cooperation is not commensurate with that of research output.
Delhi Jammu & Kashmir	:	Correlated to *Clinical Medicine* for research but not for interstate cooperation. This means that cooperation effort is less than the research effort in this field.
Haryana	:	Correlated to *Agriculture, Biology / Earth & Atmospheric Science* for research, but not correlated to any of these fields for interstate cooperation.
Himachal Pradesh	:	Correlated to *Agriculture, Biology / Earth & Atmospheric Science* for research, but not for interstate cooperation.
Orissa	:	Correlated to *Chemistry* for research but not for interstate cooperation.
Goa	:	Correlated to *Earth & Atmospheric Science* for both research and intestate cooperation, but cooperation effort is not commensurate with the research output.
Pondicherry	:	Correlated to *Clinical Medicine* for research output as well as for interstate cooperation, but the level of cooperation is not commensurate with that of research output.
Gujarat	:	Correlated to *Earth & Atmospheric Science* for interstate cooperation, but not for research.
West Bengal	:	Correlated to *Physics / Mathematics, Computer Science* for

research, but not for interstate cooperation.

Tripura : Correlated to *Physics / Mathematics* for interstate cooperation but not for research output.

Network Analysis

So far, we have examined the configurations of relationships of twenty eight states with eleven science fields on the basis of research output and interstate links. 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:

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

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.

During the five – year period, a total of 7033 cooperation links were observed, which for 756 cells, give a mean value of interstate links equal to 9.3. This is called the overall *density* of the network. About 44% of the cells (excluding the diagonal) are empty, indicating absence of any link.

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 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 get 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 (*see for example*, Wasserman and Faust[5]). 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 *Bonacich*[6] *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[7] was used to compute the eigenvector centralities of different states and the *Network Centralization Index*.

Table 4.5 presents the data on research output and centralities of different states. In the table, the states are ranked by their publication output.

Table 4.5
Research output and centrality index of different states

States	*No. of Publications*	*Centrality Index*
Maharashtra	8453	0.402
Uttar Pradesh	8127	0.422
West Bengal	6370	0.264
Delhi	5937	0.391
Karnataka	5375	0.353
Tamilnadu	4723	0.300
Andhra Pradesh	4508	0.306
Gujarat	1732	0.187
Kerala	1729	0.135
Chandigarh	1441	0.076
Madhya Pradesh	1259	0.155
Haryana	1060	0.080
Rajasthan	1021	0.083
Orissa	970	0.088
Punjab	866	0.060
Bihar	648	0.111
Meghalaya	380	0.031
Jammu & Kashmir	376	0.043
Assam	327	0.025
Himachal Pradesh	324	0.029
Goa	307	0.029
Pondicherry	288	0.034
Manipur	114	0.015
Tripura	36	0.007
Arunachal Pradesh	27	0.008
Andaman	14	0.001
Mizoram	7	0.001
Sikkim	6	0.001

Network Centralization Index = 52.97%

The calculated value of the *Network Centralization Index* (52.97%) is far above the lower limit of 0%, but still not very high. This means that the network is neither completely centralized nor completely decentralized. The values of eigenvector centrality indicate that no state dominates the network. The highest value of the centrality is 0.422.

Maharashtra has the highest rank on research output but its centrality is lower than that of UP, which means that UP has more number of links and diverse links than Maharashtra. West Bengal ranks third on the output of articles, but it ranks seventh on *Centrality Index*. This means that West Bengal has less number of links and less diverse links than expected on the basis of its research output. Bihar ranks sixteenth on research output but it ranks eleventh on *Centrality Index*, which means Bihar has made greater efforts in finding partners for research cooperation than expected on the basis of its research output.

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 effect due to size. Since we are concerned primarily with the structure of the network, we have computed an index – *Jaccard Index* – for controlling the effect of the size. *Jaccard Index* is computed by the following formula:

$$J(ij) = \frac{Cij}{Ci. + C.j - Cij}$$

where

$J(i, j)$ = Jaccard index for cell (i, j)
Cij = Number of links between any two states i and j
$Ci.$ = Total number of links of state i.
$C.j$ = Total number of links of state j.

The matrix of *Jaccard indices* represents 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 matrix of *Jaccard indices* into a graph.

The graph was developed by subjecting the matrix of *Jaccard indices* to Multidimensional Scaling (MDS) algorithm. The 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[8] was used to aesthetically improve the map yielded by the MDS algorithm. The map was 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[9].

Figure 4.9 presents the network of cooperation links of 28 states, wherein the arcs between the states indicate the strength of cooperation links above a certain threshold (*Jaccard Index* > .01), which indicates 'strong' bilateral links. It can be easily seen that the central region of the network which is occupied by UP, Bihar, Delhi, Rajasthan, Gujarat, Madhya Pradesh, Maharashtra, Karnataka and West Bengal is densely packed. The incidence of the mutual connections in this region is greater than that in the other parts of the network. The subgraph occupied by the eastern states is rather sparse, indicating lower incidence of mutual connections among these states.

The network presented in Figure 4.9 is quite revealing as it provides a synoptic view of state – by – state relationships. But the network is quite complex and difficult to comprehend. The network comprises 28 nodes and 170 arcs. It is therefore essential to find a parsimonious representation of the total configuration by clustering the states 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[10] 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 eight blocks according to their structural equivalence using the CONCOR algorithm[11] (Convergence of iterated correlations) implemented in *UCINET*. Sikkim, which is an isolate, was excluded from the analysis. The resulting configuration of relationships between the blocks may be termed as a 'block model'.

The block model was constructed as follows. The matrix of *Jaccard Index* was dichotomized by recoding the values of *Jaccard Index*:

1 if *Jaccard Index* ≥ .01

0 otherwise

The rows and columns of the resulting adjacency matrix 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. Table 4.6 presents the densities of different blocks.

The 'density matrix' was transformed into an image matrix by dichotomizing the density matrix with mean density as the cut – off value. The image matrix is presented in Table 4.7, which indicates the presence or absence of links between and within the blocks.

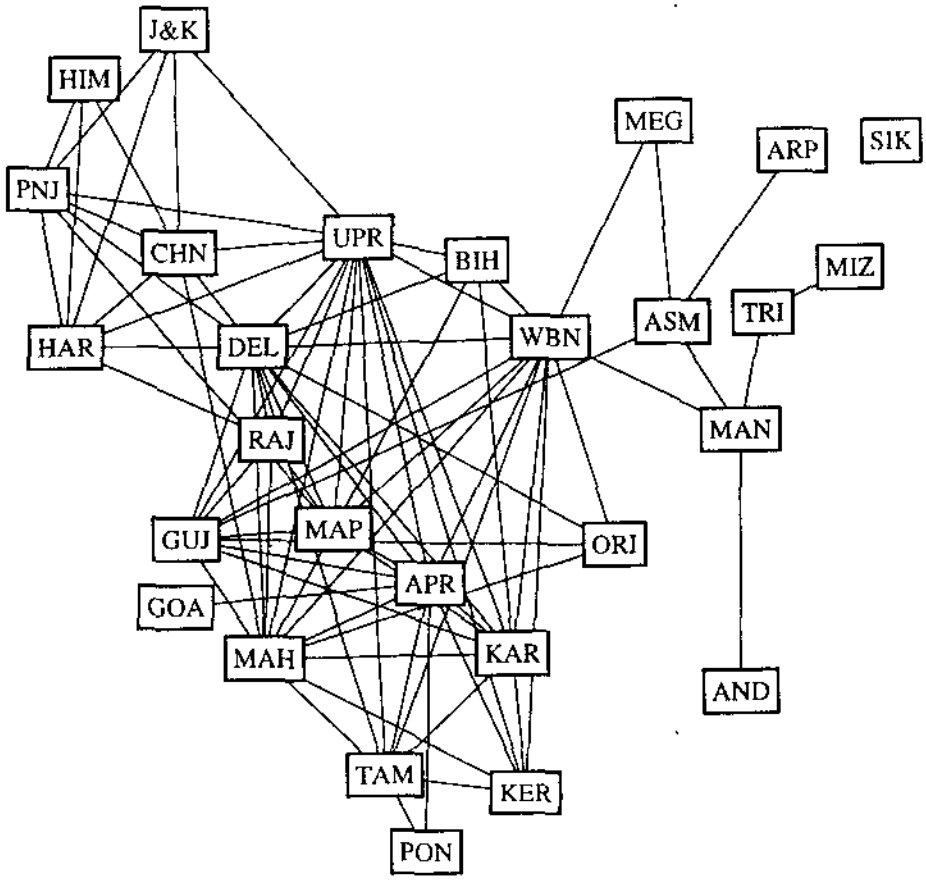

Fig. 4.9: Network of interstate cooperation

Table 4.6
Density Matrix

	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8
β_1	0.000	0.000	0.555	0.333	0.066	0.000	0.000	0.000
β_2	0.000	0.000	0.000	0.000	0.500	0.000	1.000	0.000
β_3	0.555	0.000	0.000	0.000	0.366	0.000	0.083	0.333
β_4	0.333	0.000	0.000	0.000	0.100	0.000	0.000	0.000
β_5	0.066	0.250	0.366	0.100	0.444	0.500	0.150	0.500
β_6	0.000	0.000	0.000	0.000	0.500	0.666	0.312	0.062
β_7	0.000	0.500	0.083	0.000	0.150	0.312	1.000	0.500
β_8	0.000	0.000	0.333	0.000	0.500	0.062	0.500	0.000

Legend:

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

Table 4.7
Image Matrix

	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8
β_1	0	0	1	1	0	0	0	0
β_2	0	0	0	0	0	0	1	0
β_3	1	0	0	0	0	0	0	0
β_4	1	0	0	0	0	0	0	1
β_5	0	0	0	0	1	1	1	0
β_6	0	0	0	0	1	1	0	0
β_7	0	1	0	0	1	0	1	0
β_8	0	0	0	0	1	0	0	0

Figure 4.10 presents the network of relationships between and within the blocks. It can be easily seen that the network comprises two disjointed subgraphs. The subgraph comprising blocks β_1, β_4, β_3, representing North Eastern states is separated from the rest of India. Block β_5, comprising Andhra, Bihar, Gujarat, Karnataka, Madhya Pradesh, Orissa, UP and West Bengal, occupies a central position in the network. This block is connected to three other blocks – β_8 (Rajasthan), β_6 (Goa, Pondicherry, Kerala and Tamilnadu) and β_7 (Haryana, Punjab, J&K and Chandigarh). Block β_1 (Andaman, Tripura and Assam) is a bridge between Blocks β_3 and β_4. An interesting feature of the block model is a divide between the North – Eastern states and the rest of India. North – Eastern states are relatively isolated from the rest of the country not because they do not wish to cooperate with other states, but because they do not have the capacity to cooperate. They are too small to participate in the national network of science.

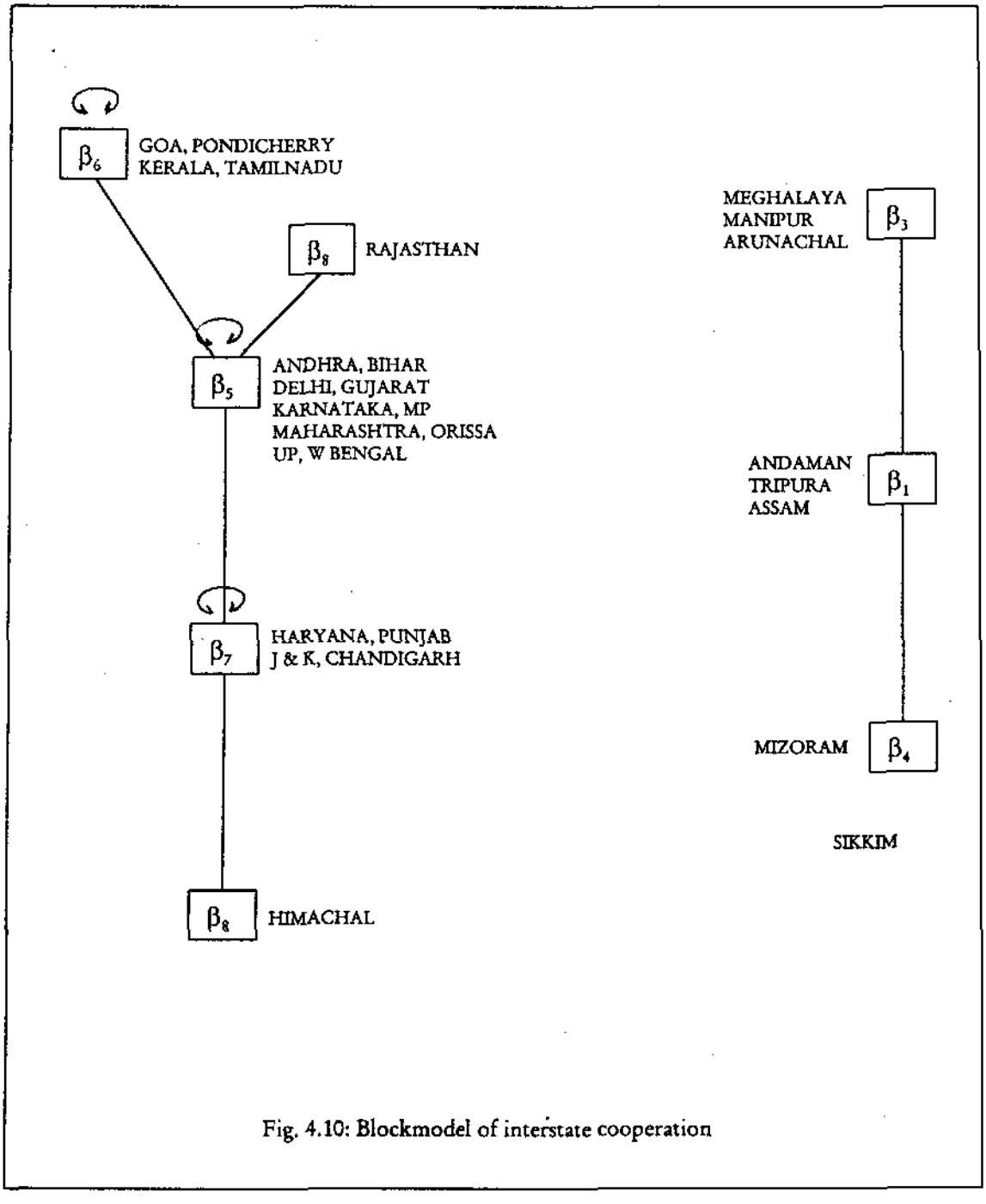

Fig. 4.10: Blockmodel of interstate cooperation

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