CONTRIBUTION OF INDIAN UNIVERSITIES TO THE MAINSTREAM SCIENTIFIC LITERATURE: A BIBLIOMETRIC ASSESSMENT

P. S. NAGPAUL

National Institute of Science, Technology and Development Studies, Dr. K. S. Krishnan Marg, New Delhi - 110 012 (India)

(Received May 2, 1994)

This paper examines the contribution of Indian universities to the mainstream scientific literature during 1987–1989 along two distinct, but inter-related dimensions of quantity and quality of research output. The quantity of output is assessed through the number of articles published in journals covered by *Science Citation Index*, while the quality of output is assessed through the impact factors of journals in which the articles are published. The impact factors are normalized to eliminate the confounding effects of their covariates, *viz.* the subject field and the nature of journal. A number of relative indicators are constructed for inter-field and inter-institution comparisons, *viz.* publication effectiveness index,[1] relative quality index,[2] activity index[3] and citability index.[4] Inter-field comparisons are made at the level of eight macrofields: Mathematics, Physics, Chemistry, Biology, Earth & Space Sciences, Agriculture, Medical Sciences and Engineering & Technology. Inter-institution comparisons cover thirty three institutions which had published at least 150 articles in three years. The structure of correlations of these institutions with eight macrofields is analyzed through correspondence analysis of the matrices of activity and citability profiles. Correspondence analysis yields a mapping of institutions which reveals the structure of science as determined by the cumulative effect of resource allocation decisions taken in the past for different fields and institutions i.e. the effect of national science policy.

Introduction

India has a network of 179 universities,[5] comprising four different types of institutions: (i) 'traditional' universities (modelled on the system of British universities), technical universities (*viz.*, institutes of technology and medicine), agricultural universities (similar to the Land Grant Colleges in USA) and research institutions deemed as universities. Together, they constitute an important segment of India's scientific potential, accounting for more than one third of the personnel engaged in research. They produce annually about 4,000 doctorates and 35,000 postgraduates in different fields of science and technology.[6] They also account for about 55–60% of Indian publications in the journals covered by *Science Citation Index* (*SCI*).[7]

This study seeks to assess the contribution of Indian universities to the mainstream scientific literature in eight macrofields[8] (Mathematics, Physics, Chemistry, Biology, Earth & Space Sciences, Agriculture, Engineering and Medical Sciences) during the three-year period 1987–89. The three-year period was chosen to smoothen any year-to-year fluctuations in the publication output of individual institutions. The main objectives of the study are:

(i) To develop indicators for inter-field and inter-institution comparison of research performance.

(ii) To construct profiles of different fields and institutions on the basis of their research output and impact.

(iii) To construct typologies of institutions based on the similarity of their profiles of research output and impact, and to assess the degree of concordance between the two typologies.

The assessment of research performance is done along two distinct, but inter-related dimensions of quantity and quality. A number of relative indicators are constructed for inter-field and inter-institution comparisons. Inter-institution comparisons and typological analysis were confined to institutions which had published at least 150 papers during the three-year period (hereafter called 'major institutions'). This was necessitated by methodological and substantive factors. The argument is that taking all institutions in the analysis would not only complicate the analysis, but would also introduce 'noise' in the data. Moreover, it is the major institutions that determine the research thrust in science.

While the assessment of quantitative dimension of research performance is straightforward, the assessment of qualitative dimension is problematic, but it has to be faced squarely. The problem of assessing the contribution of an article to the body of scientific knowledge is both real and difficult. It is real, since articles are not of homogeneous quality; it is difficult because there are no clear-cut, single valued criteria or standards for measuring quality.[9] The concept of quality is as elusive as it is pervasive.[10]

It is true that the mere fact of publication of research results in a refereed journal connotes scientific judgement based on the reputation of the journal and evaluation of referees, but this does not mean that publication counts reflect quantity as well as quality. The standards of refereeing and more specifically of what is taken to be a sufficient advance to merit publication vary from one field to another.[11] According to

Narin,[12] the jump from counting publications to ascribing scientific advancement to such counts is highly questionable without the use of citation weighting or some other quality surrogate.

At least two alternatives are proposed in the literature for quality attribution of articles. One approach is to use the number of citations received by an article in a certain time period, while the other approach is to use surrogate measures of citation performance: these measures called 'journal quality indicators' are based on the citation frequency of the journal in which the article appears. So instead of counting actual citations received by an article, the article is weighted by the journal quality indicator. In this procedure, there is no time lag due the citation process and the cost of acquiring data is drastically reduced. In this study we have used Garfield's impact factor[13] as a surrogate measure of quality.[14]

Methodology and data

Data

The data used in this paper were taken from the database created for the project 'Profile and Productivity of Academic Science'[15] sponsored by the Department of Science and Technology, Government of India. The database contains the following information for all the publications of Indian universities, compiled from *Science Citation Indexes* for 1987–1989:

(i) name of the university,
(ii) name of the journal,
(iii) impact factor of the journal,
(iv) field (or subfield) of the journal, and
(v) year of reference in the Science Citation Index

Normalization of impact factors

Garfield's impact factors are found to vary with the discipline and the type of journal. Review journals attract much more citations and therefore have higher impact factors. Hence, for cross-field comparisons, it is essential to normalize the impact factors, so as to eliminate the confounding effects of these covariates. This normalization is also necessary when we want to add up the impact of publications in different fields. The following procedure[16] was adopted for normalizing the impact factors.

Let N_j be the set of journals covered by *SCI* in field *j* and R_j be the set of review journals in the same field. Thus, the subset $[N_j - R_j]$ is the comparison set of journals in field *j*. The normalized impact factor of journal *i* in field *j* is computed as follows:

$$(NIF)_{ij} = [(GIF)_{ij}/Max(GIF)] \times 10$$

where $(GIF)_{ij}$ = Garfield's impact factor of journal *i* in subfield *j*,
$Max(GIF)$ = Highest value of impact factor of journals in the subset $[N_j - R_j]$.

Indicators of quality

In this study we have used the following indicators for inter-field and inter-institution comparisons of quality:

1. Impact rate: normalized impact per paper.
2. Publication effectiveness index (*PEI*): This measure indicates whether the impact of research in a field or institution is commensurate with the publication effort.
3. Incidence of high quality papers (*PHQ*): proportion of high quality papers in a field or institution. Papers having normalized impact $\geq$ 6.0 are considered to be of high quality.
4. Relative Quality Index (*RQI*): This index is computed as follows:

$$RQI = \frac{100 \times \text{ Proportion of high quality papers in a field (or institution),}}{\text{Proportion of high quality papers in all fields (or institution)}}$$

Profile of macrofields

Table 1 presents the publication data aggregated over all institutions and subfields of science. During the three-year period, academic institutions contributed about 18,000 publications to the mainstream scientific journals. The average annual output of about 6,000 publications constitutes roughly 55–60% of the total scientific output from India. The median value of normalized impact per paper is only 2.70,[17] implying that the quality of output is low.[18] (It may be recalled that the highest value of normalized impact of a paper by virtue of its definition is 10.0). The differences in the quantity and quality of publication output in different fields can be visualized from the data presented in Table 1.

Table 1
Output and impact of publications in major science fields

Fields	*TNP*	*TNIMP*	*Impact per papers*			*NHQ*	*PHQ*	*RQI*
			Mean	*Median*	*S.D.*			
Physics	3904	13513	3.46	2.74	2.88	734	18.8	161
Chemistry	5335	12878	2.41	1.68	2.21	403	7.5	65
Life Sciences	1975	4795	2.43	2.04	2.07	91	4.6	40
Earth/Space	648	2387	3.68	3.07	2.67	83	12.8	110
Engineering	1684	5627	3.34	2.91	2.42	209	12.4	107
Mathematics	409	1178	2.88	2.27	2.40	48	11.7	101
Medical Sci.	2137	5405	2.53	1.74	2.90	210	9.8	84
Agriculture	611	2733	4.47	4.33	2.61	168	27.5	236
Sub-Total	16703	48516	2.91	2.70	2.58	1946	11.6	100
Unidentified	1198	582	0.50	0.10	1.76	51	-	-
Total	17901	49098	2.75	2.04	2.61	1997	-	-

Notes: *TNP* - Total number of papers.
TNIMP - Total normalized impact.
NHQ - Number of high quality papers.
PHQ - Percentage of high quality papers in a field.
RQI - Relative quality index.

Confining, for the moment, our attention to absolute indicators (*viz.* number of papers, total normalized impact and number of high quality papers), it is observed that most of the research effort (as manifested in the number of publications) is concentrated in Physics and Chemistry. Chemistry accounts for the maximum number of publications, but it is Physics that accounts for the maximum amount of impact - total normalized impact (*TNIMP*). Again, there are more high quality papers in Physics than in Chemistry. Mathematics accounts for the lowest level of performance on all these indicators. Mathematics has the minimum number of publications (409 papers in three years); it accounts for the minimum amount of impact and has the minimum number of high quality papers. Agriculture and Earth & Space Sciences have the next lowest levels of performance on all these indicators. However, this does not mean that the quality of research performance in these fields is poor. It so happens that the low level of research effort in these fields masks the quality parameters when the performance of these fields is assessed through absolute indicators. Hence, we have used relative indicators for inter-field and inter-institution comparisons.

The measure *PEI* indicates whether the impact of publications in a research field is commensurate with the effort devoted to it. This is best revealed in a relational chart by the position of a field relative to the main diagonal (Fig. 1). The position of a field above the diagonal indicates that it earns greater impact than that is expected from the quantum of publication effort devoted to it, while the position of a field below the diagonal indicates that its impact is less than commensurate with the publication effort. It follows from the figure that Physics, Engineering, Agriculture and Earth & Space Sciences perform better on this indicator than Chemistry, Medical Sciences and Life Sciences. Mathematics is positioned on the main diagonal, which implies that the impact of publications in this field is precisely commensurate with the research effort devoted to it.

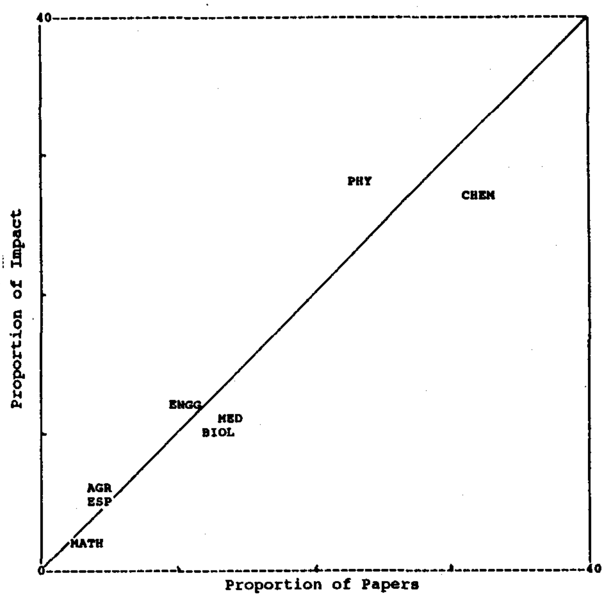

Fig. 1. Relational chart – fields

Quality performance of different fields can also be judged by the proportion of high quality papers in the field. The values of *PHQ* given in Table 1 also confirm the above trend. However, *PHQ* has a limitation; there is no standard to judge its value. A better measure for inter-field comparison of quality is the Relative Quality Index (*RQI*) which relates the incidence of high quality papers in a field to the incidence of high quality papers in all fields. The value *RQI* > 100 indicates higher than average quality, whereas the value of *RQI* < 100 indicates lower than average quality. The standing of different fields on the basis of *RQI* may be visualized from Table 1, which shows that Agriculture outperforms all other fields, followed by Physics, Earth & Space Sciences and Engineering. All these fields have *RQI* > 100, implying that they have more than average incidence of high quality papers. Mathematics, Chemistry, Medical Sciences and Life Sciences have less than average quality of output as they all have *RQI* < 100. The performance of Life Sciences on this indicator is the poorest of all fields.

Profile of major institutions

Thirty three institutions had published at least 150 papers during the three-year period. These institutions, hereafter called major institutions, account for 74.7% of all papers, 78.2% of total impact and 80.5% of all high quality papers. The names of these institutions along with the abbreviations used in the paper are given in the *Appendix*.

It is observed that these institutions account more for quality than for quantity of output, particularly in Chemistry, Mathematics and Agriculture, which implies that there is greater concentration of quality in the major institutions than that is expected on *pro rata* basis by their research effort.

Output and impact of major institutions

Table 2 presents the data on publication output and impact of major institutions and quality indicators derived therefrom, *viz.*, impact rate, publication effective index (*PEI*) and relative quality index (*RQI*). It can be easily seen from the values of *PEI* that Hyderabad outperforms all other institutions on this indicator. IISC, IITD, IITM, IITK, IITKh, Jadavpur, Poona, Hyderabad, HAU, Bombay and JNU have *PEI* > 1, implying that they earn more impact than that is commensurate with their publication effort. The impact of IITB and NEHU is just commensurate with their publication effort.

The standing of different institutions on the basis of incidence of high quality papers can be judged from the values of *RQI*. Hyderabad again outperforms all other institutions, followed by Bombay, IISC, HAU, Poona, IITK, PGIMER, IITB, IITD and IITM in that order. All these institutions have *RQI* > 100, implying that they have more than average incidence of high quality papers. The remaining institutions have less than average incidence of high quality papers.

Table 2

Publication output and impact of major institutions

		Impact Rate						
University	*TNP*	*TNIMP*	*Mean*	*Median*	*NHQ*	*PHQ*	*PEI*	*RQI*
IISc	1363	4919	3.61	2.83	247	18.12	1.24	156
BHU	905	2441	2.70	2.04	88	9.72	0.93	83
IIT/D	799	2467	3.09	2.58	88	11.01	1.06	95
IIT/M	782	2454	3.14	2.83	93	11.89	1.08	102
Delhi	711	1921	2.71	1.82	76	10.69	0.93	92
AIIMS	662	1568	2.38	1.49	69	10.42	0.82	102
IIT/K	586	1979	3.38	2.80	80	13.65	1.16	117
IIT/Kh	563	1642	2.92	2.57	46	8.17	1.07	70
PGIMER	561	1485	2.67	1.65	87	15.51	0.91	133
Jadavpur	446	1395	3.13	2.29	62	13.90	1.08	119
Punjab	442	1240	2.84	1.77	70	15.84	0.97	136
Rajasthan	404	847	2.10	1.48	33	8.17	0.41	70
IIT/B	384	1312	3.42	2.85	53	13.80	1.17	118
AMU	349	823	2.35	1.49	27	7.74	0.81	68
PAU	337	941	2.79	2.35	36	10.68	0.95	92
Osmania	316	585	1.86	1.18	10	3.16	0.64	27
IARI	304	831	2.73	1.75	36	11.84	0.94	102
Poona	296	922	3.12	2.25	44	14.86	1.07	128
Calcutta	278	758	2.73	2.27	28	10.07	0.94	86
Madras	274	622	2.27	1.47	20	7.30	0.78	63
Andhra	241	488	2.05	1.28	15	6.22	0.70	53
Gorakhpur	240	590	2.46	1.58	16	6.67	0.85	57
Hyderabad	237	982	4.14	4.14	91	38.40	1.42	330
HAU	233	783	3.36	2.90	36	15.45	1.16	133
Bombay	225	881	3.92	3.55	44	19.56	1.35	168
Roorkee	222	620	2.79	2.65	23	10.36	0.95	89
Lucknow	200	397	1.99	0.84	12	6.00	0.68	52
NEHU	200	578	2.89	2.04	25	12.50	0.99	107
JNU	185	594	3.21	2.90	17	9.19	1.10	79
MKU	163	326	2.00	1.19	9	5.52	0.68	47
Karnataka	157	299	1.91	1.02	10	6.37	0.66	55
SPU	157	355	2.26	2.08	3	1.91	0.87	16
Allahabad	150	328	2.19	1.62	10	6.67	0.76	57

We can construct a typology of institutions on the basis of *PEI* and *RQI*:

Type 1 $PEI > 1; RQI > 100$	Type 2 $PEI < 1; RQI > 100$
Type 3 $PEI > 1; RQI < 100$	Type 4 $PEI < 1; RQI < 100$

Table 3 presents the classification of major institutions into the four typology groups.

Table 3
Classification of institutions into typology groups

Type 1	Type 2	Type 3	Type 4	
IISC	AIIMS	IITD	BHU	Madras
IITM	PGMIER	IITKH	Delhi	Andhra
IITK	Punjab	JNU	Rajasthan	Gorakhpur
Jadavpur	IARI		AMU	Roorkee
IITB			PAU	Lucknow
Poona			Osmania	MKU
Hyderabad			Calcutta	SPU
HAU				Alld
Bombay				

The characteristics of these typology groups are:

Type 1 institutions publish relatively more high quality papers and less low quality papers.

Type 2 institutions publish relatively more high quality and more low quality papers.

Type 3 institutions publish relatively few high quality and also few low quality papers.

Type 4 institutions publish few high quality and more low quality papers.

Output and impact of major institutions in different fields

Tables 4 and 5 present the data on publication output and impact of major institutions in different fields. It can be easily seen that all fields are not similarly represented in all institutions. There are considerable differences in the publication output and impact of different institutions, depending upon their objectives and research competence in different fields. However, we can not comprehend these differences, since the raw data on publications and impact are confounded by the size of institutions and the size of subject fields. Hence we have translated the raw data into two indices (*viz.* Activity Index and Citability Index), wherein the effects of confounding covariates are eliminated. Activity Index was first proposed by *Frame*[19] and subsequently used among others by *Schubert* and *Braun*,[20] *Carpenter* et al.[21] Activity Index, *AI*, is computed as follows:

$$(AI)_{ij} = [(n_{ij}/n_{io})/(n_{oj}/n_{oo})] \times 100$$

where n_{ij} is the number of publications of institution i in field j,
n_{io} is the number of publications of institution i in all fields,
n_{oj} is the number of publications of all institutions in field j,
n_{oo} is the total number of publications.

Table 4
Publication output of major institutions in science fields

University	Phy	Chem	Life Sci	Esp	Eng	Math	Med	Agr	Gen	Total
IISc	416	498	82	31	218	37	20	3	58	1363
BHU	181	209	170	61	107	11	104	17	45	905
IIT/D	184	287	7	26	244	31	3	7	10	799
IIT/M	350	227	4	6	154	21	5	0	15	782
Delhi	137	273	104	20	27	7	100	8	35	711
AIIMS	7	22	75	6	3	1	536	1	11	662
IIT/K	162	236	8	22	123	26	0	0	9	586
IIT/Kh	133	243	9	20	87	39	3	19	10	563
PGIMER	8	34	53	1	10	3	437	1	14	561
Jadavpur	197	144	7	30	38	13	14	0	3	446
Punjab	97	123	64	8	21	11	82	0	36	442
Rajasthan	92	169	30	5	27	1	46	2	32	404
IIT/B	102	143	8	8	98	18	1	1	5	384
AMU	35	134	56	11	32	4	62	9	6	349
PAU	7	41	73	23	19	0	55	94	25	337
Osmania	47	141	35	22	17	4	7	2	41	316
IARI	1	21	72	29	13	6	1	83	78	304
Poona	105	97	19	6	28	10	10	1	20	296
Calcutta	67	63	59	8	19	4	40	1	17	278
Madras	49	100	34	4	12	3	23	4	45	274
Andhra	89	64	28	12	7	3	16	1	21	241
Gorakhpur	48	100	40	9	8	1	9	11	14	240
Hyderabad	107	88	20	2	4	7	8	0	1	237
HAU	1	13	74	5	5	0	46	75	14	233
Bombay	26	116	12	1	37	11	6	10	6	225
Roorkee	30	86	3	28	64	2	2	1	6	222
Lucknow	12	62	25	1	1	2	69	8	20	200
NEHU	48	85	26	3	9	1	11	9	8	200
JNU	32	33	57	23	4	3	21	2	10	185
MKU	40	48	47	2	1	1	4	2	18	163
Karnataka	34	55	19	3	4	4	7	3	28	157
SPU	39	88	14	0	7	0	2	0	7	157
Allahabad	36	58	25	1	11	0	12	0	7	150

Table 5

Impact of major institutions in science fields

University	Phy	Chem	Life Sci	Esp	Eng	Math	Med	Agr	Gen	Total
IISc	1744.70	1657.22	247.16	91.82	854.71	92.75	133.23	39.17	58.15	4918.90
BHU	583.54	457.50	380.25	219.58	388.69	15.81	284.04	96.64	14.93	2440.99
IIT/D	748.54	698.45	10.63	82.58	769.07	85.56	7.65	45.97	18.43	2466.89
IIT/M	1120.83	733.05	9.20	13.68	487.82	60.19	22.56	0.00	6.63	2453.96
Delhi	470.27	651.69	294.33	87.21	88.34	30.17	241.73	53.05	3.90	1920.69
AIIMS	23.91	61.33	158.41	19.98	7.25	2.24	1257.74	6.90	29.97	1567.73
IIT/K	587.69	791.56	10.00	81.51	435.83	72.66	0.00	0.00	0.22	1979.47
IIT/Kh	394.38	753.44	23.92	79.00	224.03	93.92	4.51	67.57	0.73	1641.51
PGIMER	64.45	31.35	129.78	3.07	31.06	16.80	1183.97	10.00	14.51	1484.99
Jadavpur	662.67	363.87	16.72	123.76	104.90	69.18	31.26	0.00	21.60	1393.96
Punjab	465.24	253.17	122.98	18.01	90.54	45.89	159.19	0.00	84.94	1239.96
Rajasthan	263.32	324.11	77.56	26.05	83.47	1.35	51.37	16.57	3.19	846.99
IIT/B	343.01	456.15	16.34	34.99	383.05	62.86	0.00	8.93	6.73	1312.05
AMU	134.34	259.32	123.63	46.01	75.22	2.62	130.58	44.69	6.66	823.05
PAU	26.84	77.60	152.48	72.00	51.28	0.00	163.43	394.54	2.49	940.65
Osmania	89.56	233.81	105.66	66.20	49.87	6.18	15.04	5.31	13.42	585.05
IARI	5.16	38.17	180.36	96.56	45.08	30.71	0.00	388.74	45.80	830.58
Poona	468.25	219.80	54.02	21.01	83.35	33.76	28.74	1.12	11.93	921.97
Calcutta	239.14	161.41	126.60	48.52	54.56	23.07	93.90	9.05	1.70	757.93
Madras	190.54	202.02	72.51	16.14	50.03	2.94	49.41	27.78	10.92	622.29
Andhra	210.72	108.43	62.70	21.60	21.68	4.46	23.71	2.71	31.50	487.51
Gorakhpur	110.84	243.09	85.86	34.27	32.97	1.31	23.40	49.11	9.30	590.16
Hyderabad	526.42	307.93	58.16	9.29	39.99	11.04	23.26	0.00	6.10	982.20
HAU	10.00	20.63	184.48	30.04	15.61	0.00	150.42	370.30	1.40	782.88
Bombay	120.17	471.24	41.61	8.18	128.99	42.61	19.34	48.50	0.60	881.22
Roorkee	217.54	190.39	7.14	92.47	165.60	15.02	4.65	6.57	10.41	619.79
Lucknow	34.84	79.64	61.75	2.30	3.04	6.85	163.85	33.38	11.53	397.19
NEHU	161.19	245.40	59.17	12.09	15.77	0.81	32.77	49.81	0.80	577.81
JNU	138.59	38.09	207.02	98.27	21.36	5.25	68.31	5.34	11.36	593.61
MKU	117.46	82.37	97.87	8.73	1.92	0.60	5.31	8.24	3.09	325.59
Karnataka	75.07	115.97	32.63	9.06	4.96	16.78	16.30	15.96	12.35	299.10
SPU	90.98	214.09	31.12	0.00	12.74	0.00	5.82	0.00	0.70	355.45
Allahabad	100.87	108.07	56.68	3.32	33.08	0.00	25.33	0.00	0.70	328.05

Here, 'all' refers to the appropriate comparison set (i.e. the set of major institutions). *CI* is computed in the same manner as Activity Index. In the computation of *AI* and *CI*, publications in multidisciplinary journals, whose field could not be identified, were ignored. The value of *AI* (or *CI*) = 100 indicates that the research effort (or impact) of an institution in a given field corresponds precisely to the average of all institutions; *AI* (or *CI*) > 100 reflects higher-than-average and *AI* (or *CI*) < 100 lower-than-average effort (or impact) of an institution in a given field.

The values of Activity Index and Citability Index for major institutions are presented in Tables 6 and 7, which show the differences in disciplinary emphasis among the institutions. In these tables, the rows represent the profiles of institutions and columns represent the profiles of fields. We can easily identify from these tables the fields of publication or citability strength. It can be easily seen from the values of Activity Index in Table 6 that the strongest field of research for IITKh is Mathematics; in contrast, the strongest field of research for IITK is Engineering; the strongest field of research for Bombay is Mathematics, whereas for Delhi, it is one of the weakest fields.

Table 6 also indicates that the distribution of Activity Index is skewed, but the degree of skewness varies considerably among the institutions. There are certain institutions which concentrate their research effort in a few fields, while there are some other institutions which distribute their research effort over many fields.

Table 7 presents the data on Citability Index for major institutions in different fields. We can easily identify from the table the fields of relative strength and weakness for different institutions. We can also compare the citability strengths (or weaknesses) of different institutions for a given field. *Nagpaul* and *Pant*[23] have proposed a 7-point scale for fixing bench marks for *AI* and *CI* for qualitative description of the relative status of a field within a country or within an institution. It is observed, for example, that Engineering is relatively the strongest field for IITD, but not so for IITKH, where Mathematics is the strongest field.

Table 6
Activity profile of major institutions

University	*Phy*	*Chem*	*Life Sci*	*Esp*	*Eng*	*Math*	*Med*	*Agr*
IISc	136	119	53	61	166	116	12	6
BHU	90	76	167	183	123	52	95	54
IIT/D	100	114	8	85	307	160	3	24
IIT/M	195	93	4	20	199	112	5	0
Delhi	87	126	130	76	40	42	116	32
AIIMS	5	11	97	24	5	6	644	4
IIT/K	120	128	12	98	211	184	0	0
IIT/Kh	103	138	14	93	156	288	4	94
PGIMER	6	19	82	5	18	22	624	5
Jadavpur	190	102	13	175	85	120	25	0
Punjab	102	95	133	51	51	111	158	0
Rajasthan	106	142	68	35	72	11	97	15
IIT/B	115	118	18	54	256	194	2	7
AMU	44	122	138	83	93	48	141	72
PAU	10	41	198	190	60	0	138	824
Osmania	73	161	108	206	61	59	20	20
IARI	2	29	269	331	57	108	3	1004
Poona	163	110	58	56	101	148	28	10
Calcutta	110	76	191	79	72	63	120	10
Madras	92	137	126	45	52	54	79	48
Andhra	173	91	108	141	32	56	57	12
Gorakhpur	91	139	150	103	35	18	31	133
Hyderabad	194	117	72	22	17	121	26	0
HAU	2	19	286	59	23	0	164	936
Bombay	51	1	66	46	12	168	205	21
Roorkee	59	125	12	334	294	38	7	13
Lucknow	29	108	117	14	6	45	300	121
NEHU	107	139	115	40	46	21	45	128
JNU	78	59	275	339	23	70	94	31
MKU	118	104	274	36	7	28	22	38
Karnataka	113	133	125	60	31	127	42	64
SPU	111	184	79	0	46	0	10	0
Allahabad	108	127	148	18	76	0	66	0

We can also compare the performance of different institutions by examining the relationship between *AI* and *CI* for specific fields. For instance, in the case of IITKH, *AI* for Physics is 103, but *CI* is 17 points lower (i.e. *CI* = 86). This implies that IITKH devotes relatively more than average effort, but earns less than average impact. On the other hand, in the case of IITM, *AI* for Chemistry is 93, but *CI* is 20 points higher (i.e. *CI* = 113). This means that IITM publishes relatively less than average number of papers, but earns more than average impact. However, we can discern these differences more systematically by plotting the values of *CI* against *AI* in a relational chart. A typical relational chart for one field (Physics) is presented in Fig. 2, as prototype example of our methodology[23] and its usefulness. In this figure, the diagonal represents a 'balanced situation' i.e. balance between research effort (publication effort) and impact.

Table 7
Citability profile of major institutions

University	*Phy*	*Chem*	*Life Sci*	*Esp*	*Eng*	*Math*	*Med*	*Agr*
IISc	129	128	51	38	152	79	25	14
BHU	86	71	159	184	138	27	105	71
IIT/D	110	107	4	69	271	144	3	33
IIT/M	164	113	4	11	172	101	8	0
Delhi	88	128	155	92	40	65	113	49
AIIMS	6	15	104	26	4	6	734	8
IIT/K	107	151	5	84	190	151	0	0
IIT/Kh	86	173	15	98	118	236	2	73
PGIMER	16	8	89	4	18	47	723	12
Jadavpur	173	100	12	183	66	208	20	0
Punjab	145	83	108	32	68	164	124	0
Rajasthan	112	145	93	63	85	7	55	35
IIT/B	94	132	13	54	253	198	0	12
AMU	59	120	153	115	79	13	144	97
PAU	10	31	164	156	47	0	156	47
Osmania	56	154	187	235	75	45	24	16
IARI	2	18	233	250	50	161	0	879
Poona	185	91	60	47	79	153	28	2
Calcutta	114	80	169	130	62	126	111	21
Madras	112	124	120	54	71	20	73	81
Andhra	166	90	139	96	41	40	47	11
Gorakhpur	69	158	150	120	49	9	36	150
Hyderabad	194	119	60	19	35	47	21	0
HAU	5	10	239	78	17	0	173	841
Bombay	49	202	48	19	126	199	20	98
Roorkee	75	118	12	308	234	102	7	19
Lucknow	32	78	162	12	7	73	381	154
NEHU	100	160	104	43	24	6	51	153
JNU	85	25	360	343	32	37	105	16
MKU	131	96	307	55	5	8	15	45
Karnataka	94	152	115	64	15	241	51	99
SPU	92	227	89	0	31	0	15	0
Allahabad	111	124	175	21	87	0	69	0

The relational chart can be divided into four quadrants according to the values of *AI* and *CI*:

Quadrant I	: $AI < 100$	$CI < 100$
Quadrant II	: $AI < 100$	$CI > 100$
Quadrant III	: $AI > 100$	$CI > 100$
Quadrant IV	: $AI > 100$	$CI < 100$

Thus, Quadrant I comprises those institutions which devote less than average research effort and also earn less than average impact. Quadrant II comprises those institutions which devote less than average research effort but earn more than average impact. Quadrant III comprises those institutions which devote more than average research effort and also earn more than average impact. Quadrant IV comprises those institutions which devote more than average research effort but earn less than average impact.

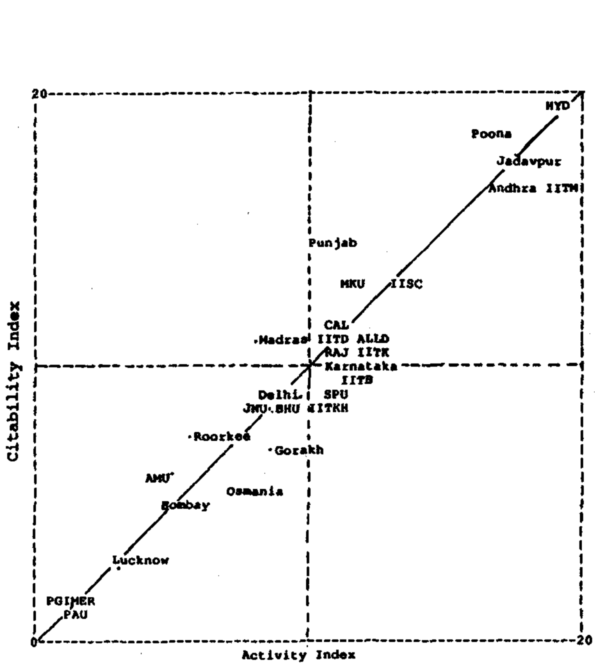

Fig. 2. Relational chart for institutions (Physics)

It is observed from Fig. 2 that there are several institutions in the first quadrant, which devote less than average effort and also earn less than average impact – *viz.* Lucknow, Bombay, AMU, Roorkee, JNU, Gorakhpur, BHU, Delhi and Osmania. Institutions located above the diagonal earn more impact than that is expected from their publication effort (e.g. AMU and Roorkee). Therefore, in spite of the fact that both relative effort and impact are below the national average, Physics deserves special attention and support in these institutions. Madras qualifies even more for special attention in this field, since it earns more than average impact for less than average research effort.

On the other hand, relative citability of institutions in the third quadrant (but below the diagonal) – NEHU, IITK, IISC, Andhra, Jadavpur and IITM – though higher than average is less than commensurate with their publication effort in the field. Institutions in the third quadrant but above the diagonal, devote more than average research effort and receive even higher impact than what is expected from their relative research effort in the field. Such institutions are Punjab, Poona, IITD, MKU, Calcutta and Rajasthan. In this quadrant, Hyderabad and Allahabad are situated on the diagonal and thus their impact corresponds precisely to their research effort.

Multidimensional analysis

In this sections, we would examine the multidimensional structure of relationships between institutions and fields. The objective is to construct a typology of institutions on the basis of similarities of their activity (or citability) profiles.

Configuration of activity profiles

The correlations and specificities of 33 major institutions with eight scientific fields on the basis of their activity profiles were examined through Correspondence Analysis[24] of the matrix of activity profiles, using the computer program CORAN. As a result of correspondence analysis, each field in the high dimensional space is projected into the low dimensional subspace of 33 institutions, whereas each institution is projected into the conjugate space of eight fields.

The eigen values of different factorial axes computed by the program indicate that the first three axes, accounting for about 85% of the total variance, yield the most parsimonious representation of the data. The remaining axes, accounting for smaller amounts of variances, represent information which does not have much bearing on the basic structure of multivariate relationships.

In Figure 3, the 7-dimensional system ($n-1$ columns) is projected into a two-dimensional space, summing up 74.1% of the total variance in the multidimensional data. The third factorial axis accounts for 10.7% of the total variance. Thus, the two-dimensional map constituted by factorial axis, ϕ_1 and ϕ_2, reveals the main features of the multidimensional data. The factorial axis ϕ_3 represents the complementary data for further analysis.

Factor ϕ_1: The first factor, which accounts for 40.4% of the total variance, is the most important element of the structure of relationships between major institutions and science fields.

On the cloud of fields, this factor is controlled by: Agriculture (AC = 10.3%; RC = 0.62), Chemistry (AC = 6.3%; RC = 0.51), Engineering (AC = 11.9%; RC = 0.50), Mathematics (AC = 8.9%; RC = 0.46), Medical Sciences (AC = 9.0%; RC = 0.19) and Physics (AC = 6.0%; RC = 0.62).

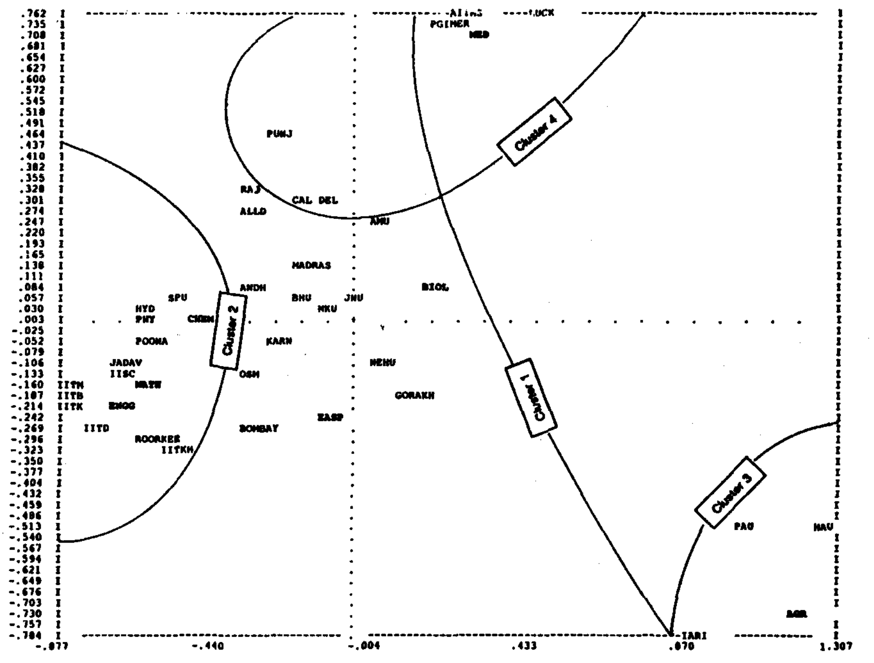

Fig. 3. Correspondence analysis of publication output (Relative position of major institutions and fields)

Agriculture and Medical Sciences, having positive coordinates on this axis, are opposed to Physics, Chemistry, Mathematics and Engineering, which have negative coordinates. Thus, the major institutions are characterized first and foremost by the opposition between Agriculture and Medical Sciences on the one hand and Physics, Chemistry, Mathematics and Engineering on the other.

On the cloud of institutions, this factor is controlled by the following clusters of institutions:

Cluster I: PAU (AC = 16.1%; RC = 0.79), HAU (AC = 23.2%; RC = 0.83), IARI (AC = 15.4%; RC = 0.59), AIIMS (AC = 3.7%; RC = 0.11), PGIMER (AC = 3.1%; RC = 0.20), Lucknow (AC = 1.7%; RC = 0.28).

Cluster II: IISC (AC = 2.8%; RC = 0.86), IITD (AC = 4.1%; RC = 0.52), IITM (AC = 4.4%; RC = 0.65), IITK (AC = 4.3%; RC = 0.74), IITKH (AC = 2.1%; RC = 0.33), Jadavpur (AC = 2.6%; RC = 0.50), IITB (AC = 4.6%; RC = 0.63), Poona (AC = 2.3%; RC = 0.77), Hyderabad (AC = 1.9%; RC = 0.42), Roorkee (AC = 2.5%; RC = 0.23), SPU (AC = 1.2%; RC = 0.24).

Cluster 1 institutions, having positive coordinates on this axis, are opposed to Cluster II institutions which have negative coordinates. In Cluster 1, AIIMS, PGIMER and Lucknow, situated around the pole of Medical Sciences, are strongly tied to this field. HAU, PAU and IARI are strongly tied to Agriculture as they are situated around the pole of this field.

Cluster 2 institutions are strongly tied to Physics, Chemistry, Mathematics and/or Engineering, depending on their vicinity to the poles of these fields.

Factor ϕ_2: The second factorial axis, accounting for 33.75% of the variance in the multidimensional data, constitutes the second most important element of the multidimensional structure of relationships between major institutions and fields.

Medical Sciences is projected on this axis with positive coordinate, whereas Agriculture is projected on this axis with negative coordinate. Thus, the second factorial axis does not provide any new information, but separates Medical Sciences from Agriculture.

On the cloud of institutions, this factor is controlled by AIIMS (AC = 33.6%; RC = 0.75), PGIMER (AC = 31.3%; RC = 0.76), Lucknow (AC = 4.7%; RC = 0.64), Delhi (AC = 1.6%; RC = 0.48), Punjab (AC = 1.6%; RC = 0.65), Calcutta (AC = 1.7%; RC = 0.34), IARI (AC = 32.1%; RC = 0.39), PAU (AC = 4.5%; RC = 0.20), HAU (AC = 4.4%; RC = 0.23).

HAU, IARI and PAU, having negative coordinates on this axis, are strongly tied to Agriculture. AIIMS, PGIMER, Punjab, Calcutta, Delhi and Lucknow, having positive coordinates on this axis, are associated with Medical Sciences.

Factor ϕ_3: This factor accounts for 10.7% of the total variance in the multidimensional data. Fig. 4 represents the main relationships between institutions and fields in the form of a vertical scale (one-dimensional representation).

On the cloud of fields, this factor is composed of Biology (AC = 35.4%; RC = 0.68), Engineering (AC = 25.2%; RC = 0.28) and Mathematics (AC = 14.7%; RC = 0.20). Biology, having negative coordinate on this axis, is opposed to Engineering and Mathematics, which have positive coordinates.

On the cloud of institutions, this factor is mainly composed of: MKU (AC = 14.7%; RC = 0.73), JNU (AC = 9.8%; RC = 0.37), IITB (AC = 7.5%; RC = 0.28); IITKH (AC = 6.3%; RC = 0.27), Bombay (AC = 5.9%; RC = 0.35), Andhra (AC = 3.7%; RC = 0.40), Osmania (AC = 3.1%; RC = 0.32), SPU (AC = 4.4%; RC = 0.23), Madras (AC = 1.2%; RC = 0.37), Calcutta (AC = 2.0%; RC = 0.30), NEHU (AC = 1.5%; RC = 0.31), Delhi (AC = 1.7%; RC = 0.43). Allahabad (AC = 3.6%; RC = 0.34).

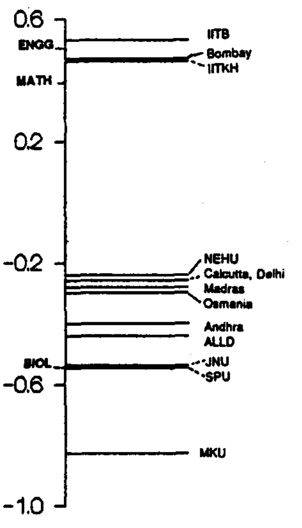

Fig. 4. Relative position of significant fields and institutions on the third dimension (Activity Index)

IITKH, Bombay and IITB, having positive coordinates on this axis, are associated with Engineering and Mathematics; they are opposed to Biology. On the other hand, Delhi, Osmania, Calcutta, Madras, Andhra, NEHU, JNU, MKU, SPU and Allahabad, having negative coordinates, are associated with Biology; they are opposed to Engineering and Mathematics.

Configuration of citability profiles

The structure of multidimensional relationships of 33 major institutions with eight scientific fields on the basis of their citability profiles was analyzed through Correspondence Analysis. The eigen values computed by the program indicate that the first three factorial axes accounting for 83.4% of the total variance yield the most parsimonious representation of the multidimensional data.

In Figure 5, the 7-dimensional system is configurated into a 2-dimensional plot, summing up 71.2% of the total variance in the multidimensional data. The third factorial axis, ϕ_3, accounts for 12.1% of the total variance.

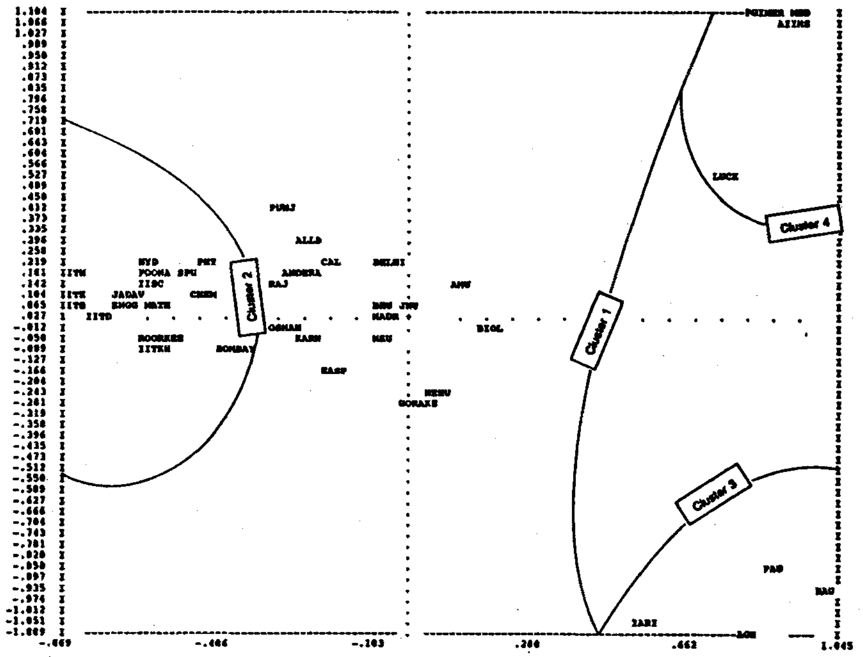

Fig. 5. Correspondence analysis of impact (Relative position of major institutions and fields)

Factor ϕ_1: The first factor, accounting for 39.1% of the total variance, is the most important element of the structure of relationships between major institutions and fields.

On the cloud of fields, this factor is controlled by Medical Sciences (AC = 34.8%; RC = 0.47), Agriculture (AC = 25.2%; RC = 0.37), Physics (AC = 9.2%; RC = 0.55), Chemistry (AC = 8.1%; RC = 0.50), Engineering (AC = 11.9%; RC = 0.53) and Mathematics (AC = 8.7%; RC = 0.38).

Medical Science and Agriculture, having positive coordinates on this axis, are opposed to Physics, Chemistry, Engineering and Mathematics, which have negative coordinates. Thus, the major institutions can be divided into two clusters, *viz.* those specializing in Agriculture/Medical Sciences and those specializing in Physics, Chemistry, Mathematics/Engineering, depending on their proximity to these fields.

On the cloud of institutions, this factor is controlled by the following clusters of institutions.

Cluster 1: AIIMS (AC = 14.8%; RC = 0.43), PGIMER (AC = 13.8%; RC = 0.40), HAU (AC = 13.7%; RC = 0.53), PAU (AC = 9.7%; RC = 0.49), IARI (AC = 5.3%; RC = 0.22), Lucknow (AC = 5.1%; RC = 0.67).

Cluster 2: IISC (AC = 2.2%; RC = 0.73), IITD (AC = 4.1%; RC = 0.56), IITM (AC = 4.0%; RC = 0.73), IITK (AC = 4.4%; RC = 0.79), IITKH (AC = 2.6%; RC = 0.65), Jadavpur (AC = 3.1%; RC = 0.51), IITB (AC = 4.9%; RC = 0.61), Poona (AC = 2.4%; RC = 0.60), Hyderabad (AC = 1.7%; RC = 0.36), Bombay (AC = 1.4%; RC = 0.32), Roorkee (AC = 3.1%; RC = 0.36).

Cluster I institutions, having positive coordinates on this axis, are associated with Medical Sciences/Agriculture. They are anticorrelated to Physics, Chemistry, Mathematics and Engineering. AIIMS, PGIMER and Lucknow are situated near the pole of Medical Sciences, whereas HAU, PAU and IARI are situated near the pole of Agriculture. These institutions are strongly tied to the field in their proximity.

Cluster 2 institutions, having negative coordinates on this axis, are strongly tied to Physics, Chemistry, Mathematics or Engineering, depending upon their proximity to the poles of these fields.

Factor ϕ_2: This factor, accounting for 32.1% of the total variance, constitutes the second most important element of the structure of relationships between major institutions and fields.

On the cloud of fields, this factor is controlled by Medical Sciences (AC = 47.3%; RC = 0.52) and Agriculture (AC = 50.0%; RC = 0.60). Medical Sciences is projected on this axis with positive coordinate, whereas Agriculture is projected on this axis with negative coordinate. Thus, this factor does not provide any new information, but demarcates institutions specializing in Agriculture from those specializing in Medical Sciences. AIIMS, PGIMER and Lucknow are correlated to Medical Sciences, whereas IARI, HAU and PAU are correlated to Agriculture.

Factor ϕ_3: This factor accounts for 12.1% of the total variance in the multidimensional data. The main relationships between institutions and fields on this axis are represented in Fig. 6 in the form of a vertical scale.

On the cloud of fields, this factor is mainly composed of: Biology (AC = 41.0%; RC = 0.78), Mathematics (AC = 24.7%; RC = 0.34), Earth & Space Sciences (AC = 9.5%; RC = 0.20) and Engineering (AC = 11.9%; RC = 0.26).

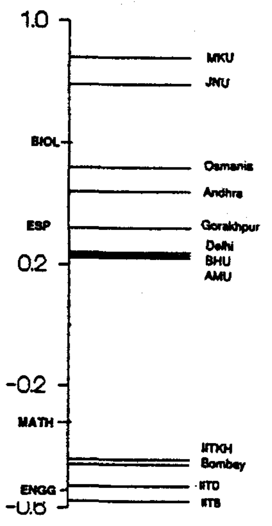

Fig. 6. Relative position of significant fields and institutions on the third dimension (Citability Index)

Biology and Earth & Space Sciences, having positive coordinates on this axis, are opposed to Mathematics and Engineering, which have negative coordinates on this axis.

On the cloud of institutions, this factor is mainly composed of the following institutions: MKU (AC = 13.4%; RC = 0.75), JNU (AC = 18.5%; RC = 0.61), Delhi (AC = 1.3%; RC = 0.52), Bombay (AC = 4.8%; RC = 0.34), Allahabad (AC = 3.4%; RC = 0.35), BHU (AC = 4.2%; RC = 0.24), Gorakhpur (AC = 23.0%; RC = 0.40), AMU (AC = 1.1; RC = 0.34), Andhra (AC = 3.6%; RC = 0.48), IITD (AC = 6.2%; RC = 0.26), IITKH (AC = 4.5; RC = 0.28), IITB (AC = 7.6%; RC = 0.38), Osmania (AC = 6.3%; RC = 0.47).

IITD, IITB, IITKH and Bombay are associated with Engineering and Mathematics. MKU, JNU, Andhra, Allahabad, Gorakhpur, Delhi, BHU and AMU are associated with Biology and Earth & Space Sciences.

Comparison of configurations

An inspection of the configurations based on activity and citability profiles indicates that the composition of the first two factorial axes is almost identical on the cloud of fields. On the cloud of institutions, the composition of the first two factorial axis is almost identical, though there are certain differences in the distances between institutions and those between institutions and fields, implying differences in the strength of relationships. However, there are certain differences in the composition of the third factorial axis.

To examine the similarities and differences in the configurations of activity and citability profiles more systematically, the configurations were compared, using the computer program FMATCH,[25] based on Cliff's algorithm.[26] The program rotates both the matrices to a compromise position. This is analogous to finding the orientation of r space and that of s space and matching the n projections in each of the two spaces. The axes of the two spaces are rotated so that the columns of the rotated matrics are as similar as possible. The program yields two-dimensional plots and computes the goodness of fit index which is equal to $+1$ for perfect fit and equal to -1 for worst fit. The coordinates of the first three factorial axes were taken into account for matching of the two configurations. The program indicated goodness of fit equal to 0.941, which implies excellent fit between the two configurations. This was expected since the compositions of the first two factorial axes (which account for more than 70% of the variance in the multidimensional data) are almost identical for both configurations. This indicates that the configurations based on activity and citability profiles are about the same. This means that the structures of relationships of major institutions with eight fields are about the same, whether based on quantity or quality of output.

Conclusions

In this study we have developed a framework and indicators for inter-field and inter-institution comparison of research performance. Relative indicators are more useful for comparative analysis than absolute indicators, since the former take into account the sociological character (i.e. size and growth rate of scientific fields) as well as the organizational character of science (i.e. the size of different institutions).

Comparative analysis based on bibliometric data, particularly the identification of strengths and potential holes in the research agenda of different institutions has important implications for national science policy, especially for allocation of resources and related policy decisions for scientific fields/institutions and impact evaluation of previous decisions.

The methodology adopted in this study (*viz.* correspondence analysis) for identifying clusters of institutions with similar profiles of research output (or impact) is superior to hierarchical cluster analysis, which does not permit multiple or cross classifications. Moreover, one can cluster either the row or column elements of a matrix with this procedure, but not both. Correspondence analysis does not have these limitations. Another advantage is that the overlapping structure in the data can be spatially represented (as maps) to reveal the correlations and specificities of different clusters of institutions to various fields.

Traditionally, mapping of science is done to reveal the cognitive structure of science. In this paper, we have demonstrated the feasibility and usefulness of mapping of science based on the similarity of activity and citability profiles of institutions. This mapping of science reveals the institutional structure of science as ordained by the national science policy. The mapping serves a practical need; it provides an information base for decision-making in science e.g. for identifying partners for cooperative research in designated fields and for monitoring the accumulation and growth of knowledge in different fields in different institutions.

*

Acknowledgements are due to Council of Scientific and Industrial Research, New Delhi, for financial support under the Scheme 'ESS Programme of Research in Applied Scientometrics'. Acknowledgements are also due to the Department of Science and Technology, Government of India, for sponsoring the project 'Profile and Productivity of Academic Science in India'.

Notes and references

1. P. S. NAGPAUL, NEERAJ PANT, Cross-national assessment of specialization patterns in Chemistry, *Scientometrics*, 27 (1993) 215–235.
2. P. S. NAGPAUL, *Scientometric Profile of Academic Science in India*, National Institute of Science, Technology and Development Studies, New Delhi, 1992.
3. A. SCHUBERT, T. BRAUN, Relative indicators and relational charts for comparative assessment of publication output and citation impact, *Scientometrics*, 9 (1986) 281–291.
4. P. S. NAGPAUL, *op. cit.* 2.
5. S. KUMAR, S. R. DAS, Y. P. SEHGAL, S. N. GANDHI, I. M. L. AHUJA, A. WAHID, N. P. SRIVASTAVA, *Outturn of Scientific and Technical Manpower in India 1984–89*, Human Resource Development Group, Council of Scientific & Industrial Research, New Delhi, 1993; All universities do not have faculties of science, engineering, medicine or agriculture.

6. A. JAIN, S. PRUTHI, *Science and Technology Indicators*, Segment Publishers, New Delhi (under publication).
7. P. S. NAGPAUL, *op. cit.* 2.
8. The papers were classified according to the method developed and successfully tested by Computer-Horizons Inc. (CHI). Journals were classified into subfields, subfields into fields and each paper was classified into the field/subfield of the journal in which it was published.
9. E. DE WEERT, A macro-analysis of quality assessment in higher education, *Higher Education*, 19 (1990) 57–72.
10. R. M. PIRSIG, *Zen and the Art of Motor Cycle Maintenance*, Corgi-books, 1974.
11. M. J. MORAVCSIK, Measures of scientific growth, *Research Policy*, 2 (1973) 266–275.
12. F. NARIN, *Evaluative Bibliometrics: The Use of Publications and Citations Analysis in the Evaluation of Scientific Activity*, Computer-Horizons Inc., New Jersey, 1976.
13. E. GARFIELD, Citation analysis as a tool in journal evaluation, *Science*, 178 (1972) 471–479.
14. Several researchers have used impact factor as a surrogate measure of quality; see for example: M. P. CARPENTER, F. GIBB, M. HARRIS, J. IRVINE, B. R. MARTIN, F. NARIN, Bibliometric Profile for British Academic Institutions: An experiment to develop research output indicators, *Scientometrics*, 14 (1988) 213–233; P. S. NAGPAUL, *op. cit.* 2.
15. The methodology of creating the database and its characteristics are described in P. S. NAGPAUL, *op. cit.*, 2.
16. B. K. SEN, K. SHAILENDRA, Evaluation of scientific research output by bibliometric method, *Scientometrics*, 21 (1992) 31–46; P. S. NAGPAUL, *op. cit.*, 2.
17. In the computation of total normalized impact, articles in multidisciplinary journals, whose fields could not be identified, were excluded.
18. The concern for poor quality of scientific research in India has been voiced by the political leadership as well as scientific leadership. Prime Minister Rajiv Gandhi spoke about the quality of Indian science at the Indian Science Congress (1986): "I think we are among the top countries in terms of number of papers our scientists produce, but how many are quoted by other scientists?" According to *C. N. R. Rao*, Director Indian Institute of Science, Bangalore: "It is disheartening to admit that despite tremendous S & T infrastructure, we have only some islands of excellence in a sea of mediocrity".
19. J. D. FRAME, Mainstream research in Latin America and Caribbean, *Interciencia*, 2 (1977) 143–148.
20. A. SCHUBERT, T. BRAUN, *op. cit.* 3.
21. M. P. CARPENTER, F. GIBBS, M. HARRIS, J. IRVINE, B. R. MARTIN, F. NARIN, *op. cit.* 14.
22. P. S. NAGPAUL, N. PANT, *op. cit.* 1.
23. P. S. NAGPAUL, *op. cit.* 2; A. SCHUBERT, T. BRAUN, *op. cit.* 3.
24. See for example, L. LEBART, A. MORINEAU, K. M. WARWICK, *Multivariate Descriptive Statistical Analysis*, John Wiley and Sons, New York, 1984.
25. FMATCH is a module of the computer program 'Multidimensional Statistics Package' (PC–MDS) developed by *S. M. Smith*, Institute of Business Management, Brigham Young University, Provho, Utah, USA.
26. N. CLIFF, Orthogonal rotation to congurence, *Psychometrika*, 31 (1966) 33–42.

Appendix

Abbreviations	List of Major Institutions
IISC	Indian Institute of Science, Bangalore
BHU	Banaras Hindu University, Varanasi
IITD	Indian Institute of Technology, Delhi
IITM	Indian Institute of Technology, Madras
Delhi	Delhi University, Delhi
AIIMS	All India Institute of Medical Sciences, New Delhi
IITK	Indian Institute of Technology, Kanpur
IITKH	Indian Institute of Technology, Kharagpur
PGIMER	Postgraduate Institute of Medical Sciences, Chandigarh
Jadavpur	Jadavpur University, Calcutta
Punjab	Punjab University, Chandigarh
RAJ	Rajasthan University, Jaipur
IITB	Indian Institute of Technology, Bombay
AMU	Aligarh Muslim University, Aligarh
PAU	Punjab Agricultural University, Ludhiana
OSM	Osmania University, Hyderabad
IARI	Indian Agriculture Research Institute, New Delhi
Poona	Poona University, Pune
Calcutta	Calcutta University, Calcutta
Madras	Madras University, Madras
ANDH	Andhra University, Waltair
Gorakhpur	Gorakhpur University, Gorakhpur
Hyderabad	Hyderabad University, Hyderabad
HAU	Haryana Agriculture University, Hissar
Bombay	Bombay University, Bombay
Roorkee	Roorkee University, Roorkee
Lucknow	Lucknow University, Lucknow
NEHU	North Eastern Hill University, Shillong
JNU	Jawaharlal Nehru University, New Delhi
MKU	Madurai Kamraj University, Madurai
KARN	Karnatak University, Dharwad
SPU	Sardar Patel University, Vidyanagar (Gujarat)
ALLD	Allahabad University, Allahabad