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Bibliometric indicators of Indian research collaboration patterns: A correspondence analysis

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International collaboration is becoming an increasingly significant issue in science. During the last few years, a large number of bibliometric studies of co-authorships have been reported. Mostly, these studies have concentrated on country-to-country collaboration, revealing general patterns of interaction. In this study we analyze international collaborative patterns as indicated in the Indian publications by tracking out multi author publications as given in Science Citation Index (SCI) database. Correspondence analysis is used for analysis and interpretation of the results.

According to correspondence analysis of the data set, Physics, Chemistry, Clinical medicine are the first, second and third largest subjects having international collaboration. USA, Italy, Germany, France, England are the top five countries with which India is collaborating. The data set shows an association between Physics and Italy, Switzerland, Algeria, Finland, South Korea, Russia, Netherlands contrasting an association between Biology & Biochemistry, Immunology, Ecology & Environment, Geosciences, Multidisciplinary subjects and England, Japan, Canada. It also shows an association between Agriculture and Philippines, Canada, Denmark in contrast to an association between Chemistry and Malaysia, Germany, France. An association between Clinical medicine, Astrophysics and England, Sweden, USA, New Zealand in contrast to an association between Agriculture and Canada, Philippines, Denmark is shown. An association between Engineering, Mathematics, Computer Science, Neuroscience and Singapore, Canada, USA in contrast to an association between Chemistry, Astrophysics and Malaysia, Spain is shown. This association of collaborating countries and disciplines almost tallies with the publication productivity of these countries in different disciplines.

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Introduction

Science is an inherently collaborative enterprise. Collaboration is a significant indicator of the nature of scientific activity. International collaboration is becoming an increasingly significant issue in science. This trend has accelerated over the past few decades particularly due to the revolution in information and telecommunication technology. This has created new possibilities for the organization of joint scientific work, specifically among geographically separated collaborators. Thus the number of authors and addresses or countries in a single paper may even exceed a hundred, a phenomenon not seen in the recent past.

During the last few years, a large number of bibliometric studies of co-authorships have been reported in the literature. Mostly, these studies have concentrated on country-to-country collaboration, revealing general patterns of interaction. Qin made a study of co-authorships in the journal *Philosophical Transactions* and found that "interinstitutional and international collaboration seem to have become increasingly prevalent, accounting for more than 30% of all co-authored papers in the more recent years" (QIN, 1994). The major forces governing the network of collaboration seem to be the size of national research and development (R&D) systems and the geographical distances separating them. The interactions are also dependent on language, cultural, and political barriers (ANDERSON & PERSSON, 1993). Katz analysed the number of co-authored articles as a function of geographical distances among universities in Australia, Canada and the UK (KATZ, 1994). He found that collaboration decreases with distance between the universities studied. In most networks of this kind, the size of the nodes and the distances separating them will explain a great deal of the variation in collaboration. Katz is of the opinion that there is lack of empirical evidence on what size really means in terms of university collaboration. However, the rapidly changing technical, economic, and political structures of today will presumably also show up in changed country-to-country interactions within science. Melin presents a case study of one university and its collaborative pattern, which among other things demonstrates the significance of collaboration with external institutions (MELIN, 1996).

Need and objective of the study

Collaboration is a significant indicator of the nature of scientific activity. In the transition between 'little science' and 'big science' the nature of collaborative activity has changed to some extent from that between individual scientists to one mediated by organizations, or national and international bodies. From the co-authorship data, it is possible to obtain information on international collaboration, inter-state collaboration, inter-institutional collaboration, and individual collaboration. There has been no study carried out comprehensively analysing Indian research collaboration in all the fields of

science and technology for a long period of time using bibliometric indicators. The present study analyses international research collaborations as given in multi-authored Indian publications from 1993 to 2000 using correspondence analysis. An effort is made to analyse discipline/country collaboration pattern of Indian science publications as given in SCI database. Correspondence analysis is used for the analysis and interpretation of the data set.

Methods

To achieve a higher degree of standardization in bibliometrics is by no means an easy task. Apart from bibliometricians, responsibility lies with database producers, journal publishers and editors who need to formalize and standardize their procedures and methods more rigorously. Usually, for international collaboration study using bibliometric indicators, author affiliation as given in the multi-authored publications is considered. While some journals link individual authors with their institutions, others list all institutional addresses without making explicit the relationship between the authors and the addresses. In many journals it is difficult to identify different document types and some have different definitions of a particular document type. Hence the bibliometricians have to be familiar with the data sources available and carefully select those most likely to answer the questions under study. For the present study, SCI database on CD-ROM is considered, covering a period from 1993 to 2000. The database gives multiple addresses but does not relate the author names with affiliation. The publications having multiple addresses and containing 'India' as keyword in at least one of the author affiliations is identified for carrying out collaborative pattern analysis. Author affiliation is represented in the standard form having Institution name and country name in a standardized form. This is mounted on a MySQL database and PHP script is used to extract the information from the MySQL database. The records are classified into 23 different subject categories based on the journal classification of Institute of Scientific Information, USA. The different disciplines and their abbreviations are given in the Appendix. The top ten collaborating countries in different disciplines are extracted and these countries' collaboration in other disciplines is also extracted. The resulting dataset is given in Table 1.

Analysis of results wherein more variables are involved is not an easy task, if one wishes to account for all available information throughout the analysis. For example in case of publication productivity analysis of different institutions over a period of time, the standard outputs for comparing production tend to be graphs of the type: production per discipline per year, production per institute per year, and production per institute per discipline. However, in such instance, one dimension of the data is being ignored not only in the graph but also in the calculation (DORE, 2001).

Table 1. Country and number of collaborations in different disciplines

Country/discipline	AGD	ASD	BID	CHD	CLD	CSD	ECD	EGD	EVD	GED	IMD	LAD	MBD	MCD	MSD	MTD	NED	OTH	PHD	PLD	PMD	PSD	SSD
'ALGERIA'	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
'AUSTRALIA'	30	66	11	101	128	3	0	28	37	30	6	0	6	6	16	4	5	15	65	29	2	1	1
'AUSTRIA'	5	7	8	15	26	0	0	3	2	5	1	0	3	3	6	1	3	1	34	2	1	0	0
'BELGIUM'	3	22	20	46	23	1	0	11	4	3	3	0	9	9	2	4	0	8	67	29	4	0	0
'BRAZIL'	2	37	12	16	42	0	0	9	3	6	2	0	2	7	7	0	1	7	268	5	0	0	0
'CANADA'	62	23	43	169	114	31	1	118	39	35	6	0	10	14	29	55	17	13	251	50	6	0	0
'DENMARK'	23	23	7	63	19	2	0	6	4	2	2	0	6	2	0	5	0	7	28	5	10	0	0
'ENGLAND'	46	96	149	269	460	7	0	103	28	68	46	0	42	53	45	9	8	35	407	94	15	0	1
'FINLAND'	4	5	8	21	10	0	0	3	0	3	1	0	2	4	2	3	3	2	178	1	1	0	0
'FRANCE'	23	147	72	272	176	2	0	67	15	81	11	0	24	21	60	21	3	35	949	28	6	0	0
'GERMANY'	39	148	139	465	126	16	0	202	42	115	13	0	59	49	94	32	15	49	1560	91	32	0	0
'HONG-KONG'	1	8	2	20	37	1	0	7	4	4	0	0	3	5	2	6	0	0	13	0	1	0	0
'ISRAEL'	5	11	12	31	23	6	0	5	2	2	5	0	6	5	18	7	0	10	21	9	0	0	0
'ITALY'	6	185	49	227	98	2	0	101	3	42	1	0	8	2	63	19	3	35	2597	9	3	0	0
'JAPAN'	89	62	97	281	218	7	0	103	33	77	39	0	24	73	95	8	16	46	496	73	12	0	0
'MALAYSIA'	2	0	3	132	19	0	0	9	1	0	0	0	1	1	5	1	0	8	10	0	2	0	0
'NETHERLANDS'	28	51	11	53	43	5	3	17	15	7	9	0	10	12	5	15	2	7	903	16	4	0	0
'NEW-ZEALAND'	1	5	6	12	25	0	1	4	1	5	1	0	9	2	2	0	0	2	7	4	0	1	0
'NORTH-IRELAND'	1	22	24	4	6	0	0	0	0	0	1	0	0	13	2	0	0	3	37	13	0	0	0
'PEOPLES-R-CHINA'	12	20	11	55	55	0	0	28	2	4	4	0	0	15	8	2	2	7	476	5	1	0	0
'PHILIPPINES'	28	0	5	0	11	0	0	0	12	0	1	0	3	0	0	0	2	2	0	14	0	0	0
'RUSSIA'	3	32	20	68	15	0	0	32	0	38	1	0	4	3	7	2	0	6	697	3	0	0	0
'SCOTLAND'	13	8	26	34	37	0	0	4	16	9	7	0	3	13	4	2	2	3	28	26	3	0	0
'SINGAPORE'	0	0	5	5	11	2	2	39	1	1	0	0	4	2	20	5	3	4	16	3	1	0	0
'SOUTH-KOREA'	2	4	5	30	11	2	0	15	2	5	0	0	1	3	4	1	0	0	399	2	0	0	0
'SPAIN'	2	40	11	85	32	0	0	16	1	12	8	0	7	6	12	6	3	13	406	10	6	0	0
'SWEDEN'	6	18	27	25	53	2	0	15	9	12	10	0	6	8	16	2	6	7	130	3	1	0	0
'SWITZERLAND'	4	9	16	72	110	0	0	29	1	7	6	0	16	4	6	4	0	3	1136	1	0	0	0
'USA'	187	659	610	1205	1397	162	6	578	143	292	155	0	272	139	245	161	123	272	6874	261	95	4	5

The graphical representation approach leads to genuine loss of information. To avoid such a loss, it is preferable to employ a multidimensional technique of data reduction such as correspondence analysis (DORE et al., 1996). Correspondence analysis is a tool commonly used in many disciplines to identify and visualize the association between two or more categorical variables. What makes correspondence analysis a very versatile tool to use comes from the construction of a joint low-dimensional space that depicts the level of association between two or more categorical variables. As a result of this feature, correspondence analysis has gained a positive reputation as a necessary tool for the data analysts in nearly all disciplines (BEH, 1999). Correspondence analysis has several advantages over other methods of analysis: it was specifically designed to compare profiles or patterns; it is a multidimensional method that achieves appropriate data reduction, filters out noise, and objectifies correlations among variables; it is a method that provides graphic output such as maps that are easier to grasp than series of numbers (BENZECRI, 1992).

In this paper correspondence analysis is carried out using a freeware known as DTM (Data and Text Mining) software (available at http://www.lebart.org), devoted to exploratory analysis of multivariate numerical and textual data.

Correspondence analysis of collaborative pattern

According to Table 2, the relative weights of Physics (0.497), Chemistry (0.104), Clinical Medicine (0.092) are high indicating the fact that these are the first, second and third largest subjects having international collaboration. Similarly according to Table 3, the corresponding heavy relative weights with respect to countries are USA (0.381), Italy (0.095), Germany (0.091), France (0.055) and England (0.055).

According to Table 4 the four cumulative Eigenvalues represent more than 80 per cent of the inertia present in the data; hence one may consider all the four planes to be a fairly good representation of the dispersion present in the data.

According to plane of projection (Figure 1), the first axis separates Algeria, South-Korea, Netherlands, Italy, Russia, Germany from Philippines, Scotland, Australia, New-Zealand, Denmark, Singapore. Similarly, it separates Multidisciplinary Subjects, Physics, Chemistry, Astrophysics from Agriculture, Ecology & Environmental Science.

For a more specific interpretation of first axis, one has to look into the contribution of both collaborating countries and disciplines. Nearly 78% of the inertia on the first axis comes from Physics (45.6) on the positive side and Clinical Medicine (11.7), Agriculture (7.5), Plant and Animal Science (7.1), Chemistry (7.3) on the negative side.

However, there are many other disciplines because of their small relative weights do not bring major contributions but are significantly present on the first axis because of their high relative contribution. One must also consider Biology & Biochemistry (0.49),

Immunology (0.45), Ecology/Environment (0.51), Geosciences (0.32), Multi-disciplinary Subjects (0.44) on the negative side.

In order to interpret more specifically, one has to consider the collaborating countries. More than 50% of the inertia on the first axis comes from Italy (18.5), Switzerland (8.6) on the positive side and England (13.7), Japan (8.8), Canada (6.8) on the negative side. However, there are many other countries because of their small relative weights do not bring major contributions but are significantly present on the first axis because of their high relative contribution. One must also consider Algeria (0.91), Finland (0.71), South Korea (0.88), Russia (0.85) and Netherlands (0.77) on the positive side.

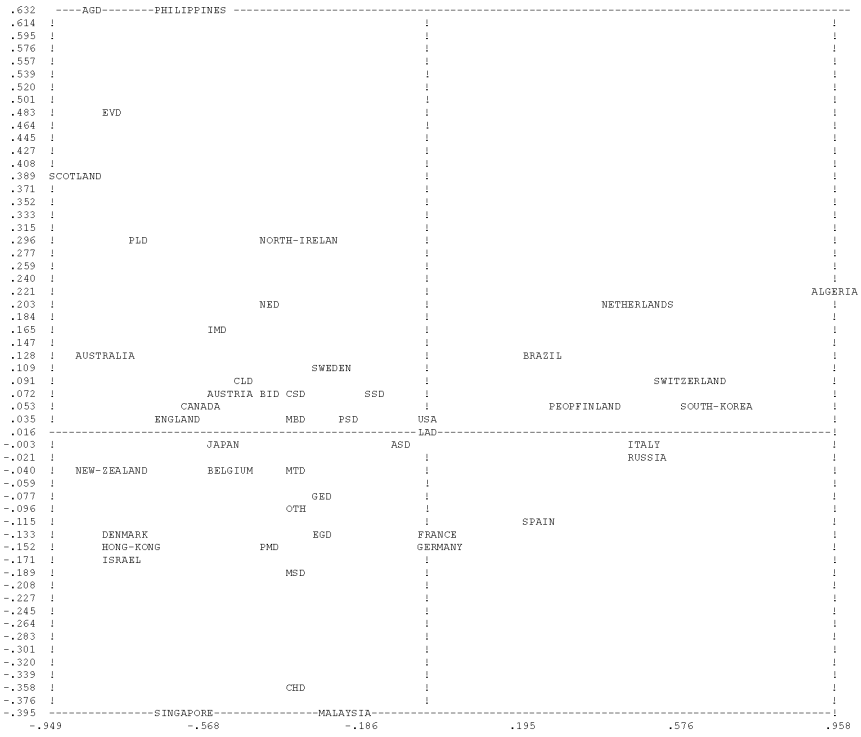

Figure 1. Plane of projection of 52 points on axis 1 and 2

Table 2. Coordinates and contributions along 4 axis for active column points

Identifiers	Weight distribution			Coordinates						Absolute contribution						Relative contribution					
AGD	0.017	1.62	*	–0.81	0.63	–0.67	–0.2	0	*	7.5	23.2	29.8	3.4	0	*	0.4	0.25	0.28	0.02	0	*
ASD	0.047	0.17	*	–0.08	–0.01	0.12	–0.12	0	*	0.2	0	2.7	3.4	0	*	0.04	0	0.09	0.09	0	*
BID	0.039	0.27	*	–0.36	0.06	0.22	0.03	0	*	3.4	0.5	7.5	0.1	0	*	0.49	0.02	0.19	0	0	*
CHD	0.104	0.3	*	–0.32	–0.37	–0.16	–0.17	0	*	7.3	47.9	9.8	15.6	0	*	0.35	0.45	0.08	0.1	0	*
CLD	0.092	0.34	*	–0.44	0.08	0.28	–0.03	0	*	11.7	2.1	27.6	0.4	0	*	0.57	0.02	0.23	0	0	*
CSD	0.007	0.87	*	–0.33	0.06	–0.13	0.6	0	*	0.5	0.1	0.4	12.2	0	*	0.13	0	0.02	0.41	0	*
ECD	0	1.83	*	–0.02	0.03	–0.04	0.61	0	*	0	0	0	0	0	*	0	0	0	0.2	0	*
EGD	0.043	0.3	*	–0.25	–0.14	–0.11	0.4	0	*	1.8	2.9	2.1	34.4	0	*	0.21	0.07	0.04	0.55	0	*
EVD	0.012	1.18	*	–0.77	0.48	–0.39	–0.07	0	*	4.6	9	6.6	0.3	0	*	0.51	0.2	0.13	0	0	*
GED	0.024	0.24	*	–0.28	–0.08	0.05	0.01	0	*	1.2	0.5	0.2	0	0	*	0.32	0.03	0.01	0	0	*
IMD	0.009	0.51	*	–0.48	0.16	0.32	–0.03	0	*	1.4	0.8	3.6	0	0	*	0.45	0.05	0.2	0	0	*
LAD	0	1	*	0	0	0	0	0	*	0	0	0	0	0	*	0	0	0	0	0	*
MBD	0.015	0.32	*	–0.3	0.03	0.17	0.11	0	*	0.9	0	1.6	0.9	0	*	0.28	0	0.09	0.04	0	*
MCD	0.013	0.72	*	–0.54	0.05	0.24	–0.09	0	*	2.6	0.1	2.9	0.5	0	*	0.4	0	0.08	0.01	0	*
MSD	0.021	0.46	*	–0.33	–0.2	–0.01	0.3	0	*	1.5	2.9	0	9.7	0	*	0.23	0.09	0	0.2	0	*
MTD	0.01	0.73	*	–0.29	–0.05	–0.32	0.51	0	*	0.6	0.1	4.1	13.2	0	*	0.12	0	0.14	0.36	0	*
NED	0.006	0.56	*	–0.37	0.2	–0.07	0.4	0	*	0.6	0.8	0.1	4.8	0	*	0.25	0.07	0.01	0.29	0	*
OTH	0.017	0.18	*	–0.28	–0.1	0.04	0.01	0	*	0.9	0.6	0.1	0	0	*	0.44	0.06	0.01	0	0	*
PHD	0.497	0.14	*	0.37	0.04	–0.01	–0.01	0	*	45.6	2.1	0.4	0.2	0	*	0.99	0.01	0	0	0	*
PLD	0.022	0.77	*	–0.7	0.29	–0.05	–0.08	0	*	7.1	5.9	0.2	0.7	0	*	0.63	0.11	0	0.01	0	*
PMD	0.006	0.63	*	–0.39	–0.17	–0.11	–0.05	0	*	0.6	0.5	0.3	0.1	0	*	0.24	0.04	0.02	0	0	*
PSD	0	0.93	*	–0.2	0.03	0.19	–0.02	0	*	0	0	0	0	0	*	0.04	0	0.04	0	0	*
SSD	0	0.87	*	–0.14	0.06	0.13	–0.01	0	*	0	0	0	0	0	*	0.02	0	0.02	0	0	*

Hence the first axis essentially shows an association between Physics and Italy, Switzerland, Algeria, Finland, South Korea, Russia, Netherlands contrasting an association between Biology & Biochemistry, Immunology, Ecology & Environment, Geosciences, Multidisciplinary Subjects and England, Japan, Canada.

For a more specific interpretation of second axis, an analysis of the contribution of both collaborating countries and disciplines is carried out. More than 70% of the inertia on the second axis comes from Agriculture (23.2) on the positive side and Chemistry (47.9) on the negative side. As far as collaborating countries are concerned, more than 70% of the inertia comes from Philippines (33.9) on the positive side and Malaysia (37.6) on the negative side. Due to their high relative contribution we can consider Germany (0.32), France (0.33) on the negative side though they have less relative weights.

Hence the second axis is essentially an association between Agriculture and Philippines in contrast to an association between Chemistry and Malaysia, Germany, France.

For a more specific interpretation of third axis, an analysis of the contribution of both collaborating countries and disciplines is carried out. Nearly 57% of the inertia on the third axis comes from Clinical medicine (27.6) on the positive side and Agriculture (29.8) on the negative side. Due to small relative weight, the contribution of

Astrophysics (0.09) on the positive side of the third axis is less but due to its high relative contribution it is significantly present on the third axis and hence one may consider this also.

Table 3. Coordinates and contributions along 4 axis for active row points

Identifiers	Weight distribution			Coordinates						Absolute contribution						Relative contribution					
ALGERIA	0	1.01	*	0.96	0.2	–0.09	–0.06	0	*	0.1	0	0	0	0	*	0.91	0.04	0.01	0	0	*
AUSTRALIA	0.016	0.99	*	–0.81	0.11	–0.06	–0.21	0	*	7.1	0.7	0.2	3.7	0	*	0.66	0.01	0	0.05	0	*
AUSTRIA	0.003	0.43	*	–0.48	0.07	0.18	–0.04	0	*	0.5	0.1	0.4	0	0	*	0.53	0.01	0.08	0	0	*
BELGIUM	0.007	0.68	*	–0.52	–0.05	0.06	–0.18	0	*	1.3	0.1	0.1	1.2	0	*	0.39	0	0	0.05	0	*
BRAZIL	0.012	0.18	*	0.29	0.12	0.18	–0.1	0	*	0.6	0.5	1.4	0.5	0	*	0.45	0.08	0.17	0.05	0	*
CANADA	0.03	0.71	*	–0.58	0.04	–0.41	0.35	0	*	6.8	0.1	19.7	18.1	0	*	0.48	0	0.24	0.17	0	*
DENMARK	0.006	1.56	*	–0.75	–0.15	–0.55	–0.44	0	*	2.2	0.5	6.8	5.6	0	*	0.36	0.01	0.19	0.13	0	*
ENGLAND	0.055	0.52	*	–0.61	0.02	0.32	–0.08	0	*	13.7	0.1	20.9	1.9	0	*	0.73	0	0.19	0.01	0	*
FINLAND	0.007	0.23	*	0.4	0.05	–0.08	–0.07	0	*	0.8	0	0.2	0.2	0	*	0.71	0.01	0.03	0.02	0	*
FRANCE	0.055	0.06	*	0	–0.14	0.02	–0.09	0	*	0	3.7	0.1	2.1	0	*	0	0.33	0.01	0.12	0	*
GERMANY	0.091	0.07	*	–0.02	–0.15	–0.12	0.03	0	*	0	7.2	5	0.3	0	*	0.01	0.32	0.2	0.01	0	*
HONG–KONG	0.003	1.34	*	–0.74	–0.16	0.28	0.06	0	*	1.2	0.3	1	0.1	0	*	0.41	0.02	0.06	0	0	*
ISRAEL	0.005	1.1	*	–0.74	–0.19	0.05	0.23	0	*	1.8	0.6	0	1.2	0	*	0.49	0.03	0	0.05	0	*
ITALY	0.095	0.31	*	0.54	–0.02	–0.05	–0.03	0	*	18.5	0.1	1	0.5	0	*	0.95	0	0.01	0	0	*
JAPAN	0.051	0.36	*	–0.51	–0.01	–0.05	–0.04	0	*	8.8	0	0.5	0.3	0	*	0.72	0	0.01	0	0	*
MALAYSIA	0.005	3.78	*	–0.78	–1.45	–0.56	–0.66	0	*	2.2	37.6	6.3	11.6	0	*	0.16	0.55	0.08	0.12	0	*
NETHERLANDS	0.033	0.28	*	0.45	0.2	–0.13	–0.08	0	*	4.6	4.6	2.2	0.9	0	*	0.73	0.14	0.06	0.02	0	*
NEW–ZEALAND	0.002	1.48	*	–0.81	–0.04	0.57	–0.07	0	*	1	0	2.9	0	0	*	0.45	0	0.22	0	0	*
NORTH–IRELAN	0.003	2.15	*	–0.4	0.28	0.53	–0.28	0	*	0.4	0.9	3.8	1.3	0	*	0.08	0.04	0.13	0.04	0	*
CHINA	0.019	0.17	*	0.33	0.05	–0.02	–0.06	0	*	1.4	0.2	0	0.4	0	*	0.64	0.02	0	0.02	0	*
PHILIPPINES	0.002	10.58	*	–1.69	2.16	–1.52	–0.59	0	*	4.1	33.9	19.2	3.7	0	*	0.27	0.44	0.22	0.03	0	*
RUSSIA	0.026	0.32	*	0.52	–0.03	–0.07	–0.05	0	*	4.7	0.1	0.5	0.3	0	*	0.85	0	0.01	0.01	0	*
SCOTLAND	0.007	1.4	*	–0.95	0.38	0	–0.29	0	*	4	3.2	0	2.6	0	*	0.64	0.1	0	0.06	0	*
SINGAPORE	0.003	3.34	*	–0.61	–0.39	–0.14	1.47	0	*	0.8	1.8	0.2	35.7	0	*	0.11	0.05	0.01	0.65	0	*
SOUTH–KOREA	0.013	0.44	*	0.62	0.05	–0.11	–0.02	0	*	3.5	0.1	0.7	0	0	*	0.88	0	0.03	0	0	*
SPAIN	0.019	0.11	*	0.24	–0.13	–0.03	–0.11	0	*	0.7	1.1	0.1	1.2	0	*	0.53	0.16	0.01	0.12	0	*
SWEDEN	0.01	0.24	*	–0.27	0.1	0.23	0.1	0	*	0.5	0.4	2.1	0.4	0	*	0.3	0.05	0.23	0.04	0	*
SWITZERLAND	0.039	0.4	*	0.57	0.09	0.03	–0.05	0	*	8.6	1	0.1	0.5	0	*	0.82	0.02	0	0.01	0	*
USA	0.381	0.02	*	0.01	0.03	0.06	0.05	0	*	0	1.2	4.7	5.5	0	*	0	0.06	0.21	0.19	0	*

Table 4. Four Eigenvalues (sum = 0.2788)

Sl	Eigenval.	Perc.	Cumul.	Histogram of values
1	0.14945	53.60	53.60	**********
2	0.02972	10.66	64.25	**********
3	0.02603	9.34	73.59	*********
4	0.02036	7.30	80.89	*******

Similarly looking at the collaborating countries, more than 59% of the contribution comes from England (20.9) on the positive side and Canada (19.7), Philippines (19.2) on the negative side. As the relative contribution of Sweden (0.23), USA (0.21), New-Zealand (0.22) are high on the positive side, though their relative weights are less, one can consider them also. Similarly Denmark (0.19) can be considered on the negative side, as its relative contribution is high.

Hence the third axis essentially shows an association between Clinical medicine, Astrophysics and England, Sweden, USA, New Zealand on the positive side in contrast to an association between Agriculture and Canada, Philippines, Denmark.

For a more specific interpretation of fourth axis, we again look into the contribution of both collaborating countries and disciplines. More than 70% of the inertia on the fourth axis comes from Engineering (34.4), Mathematics (13.2), Computer Science (12.2) on the positive side and Chemistry (15.6) on the negative side. However, there are many other disciplines because of their small relative weights do not bring major contributions but are significantly present on the first axis because of their high relative contribution. We must also consider Neuroscience (0.29) on the positive side and Astrophysics (0.09) on the negative side. Nearly 65% of the inertia comes from Singapore (35.7), Canada (18.1) on the positive side and Malaysia (11.6) on the negative side. We may also consider countries whose relative contribution are high though their relative weights are less and do not significantly present on the fourth axis. Such countries are USA (0.19) on the positive side and Spain (0.12) on the negative side.

Hence the fourth axis essentially shows an association between Engineering, Mathematics, Computer Science, Neuroscience and Singapore, Canada, USA in contrast to an association between Chemistry, Astrophysics and Malaysia, Spain.

Conclusions

The result of this study demonstrates the suitability of correspondence analysis in analyzing collaborative patterns of a country in different disciplines. The study shows how the data can be displayed in an easy readable format using correspondence analysis.

Correspondence analysis of the collaborative pattern of Indian publications shows an association between Physics and Italy, Switzerland, Algeria, Finland, South Korea, Russia, Netherlands contrasting an association between Clinical Medicine, Biology & Biochemistry, Immunology, Ecology & Environment, Geosciences, Multidisciplinary subjects and England, Japan, Canada.

It also shows an association between Agriculture and Philippines, Canada, Denmark in contrast to an association between Chemistry and Malaysia, Germany, France. An association between Clinical medicine, Astrophysics and England, Sweden, USA, New Zealand is shown. An association between Engineering, Mathematics, Computer Science, Neuroscience and Singapore, Canada, USA in contrast to an association between Chemistry, Astrophysics and Malaysia, Spain is shown. These associations are shown in Table 5.

Table 5. International collaborative patterns in different disciplines

Agricultural Science	England Japan Canada Philippines Denmark	Ecology/Environment	England
Astrophysics	Sweden USA New-Zealand England Spain	Geosciences	England
Biology/Biochemistry	England	Immunology	England
Chemistry	England Japan Canada Malaysia Germany France Spain	Molecular Biology/Genetics	Singapore Canada USA
Clinical Medicine	England Japan Canada Sweden USA New-Zealand	Neuroscience	Canada Singapore USA
Mathematics	Singapore Canada USA	Multidisciplinary	England
Computer Science	Singapore Canada USA	Physics	Italy Switzerland Algeria Finland South Korea Russia Netherlands
Engineering	Singapore Canada USA	Plant/Animal Science	England Japan Canada

This analysis of collaborative patterns as revealed in Indian publications almost tallies with the publication production analysis carried out by KING (2004). While analyzing publication patterns of 31 countries for a period from 1993–1997 and 1998–2001 based on SCI publication and citation count, King observed that Russia is relatively strong in the physical sciences and engineering, and weak in the life sciences; Japan shows strengths in the physical sciences and engineering; France is strong in mathematics; Germany has the highest impact in the physical sciences; and the UK has the highest impact in this group in the medical, life and environmental sciences and is highly placed in mathematics, but does not show as strongly in the physical sciences and engineering.

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Appendix

AGD	Agricultural Sciences	LAD	Law
ASD	Astrophysics	MBD	Molecular Biology & Genetics
BID	Biology & Biochemistry	MCD	Microbiology
CHD	Chemistry	MSD	Materials Science
CLD	Clinical Medicine	MTD	Mathematics
CSD	Computer Science	NED	Neuroscience
ECD	Economics & Business	OTH	Multidisciplinary
EDD	Education	PHD	Physics
EGD	Engineering	PLD	Plant and Animal Science
EVD	Ecology/Environment	PMD	Pharmacology
GED	Geosciences	PSD	Psychology and Psychiatry
IMD	Immunology	SSD	Social Science