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India's Collaboration with Australia in Science and Technology: A Scientometric Study of Co-Authored Papers During 1995-1999

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Abstract

International collaborations are being viewed as an important instrument for the advancement of science throughout the world, particularly by the developing countries. India could well realise the significance of international collaboration in science and hence has, therefore, signed various S&T collaboration agreements with many developed and developing countries. With Australia also such collaboration is starting to take off at the government level, but at the institutional level it already exists. In this study the scientific collaboration between India and Australia has been studied on the basis of the number of joint publications brought out by Indian and Australian scientists, as reflected through co-authored papers during the period 1995-1999. The study reveals the extent, mode, and direction of collaborative research between the two nations. It also has been attempted to crystallise and identify the priority S&T areas for collaborative research between the two countries. The impact of such collaborative research has been studied through the analysis of impact factor of publications where this joint research is published. It has been revealed that the average value of impact factor per paper for multilateral papers is far above the average impact factor of all papers. It is also found that in about 38% of the India-Australian collaborated papers the other countries were also involved, which included the USA, the UK, Russia, New Zealand, France, Switzerland, and even Italy, Japan and China. The study revealed the present status of collaboration between Australia and India in S&T, and such a study can help the policy makers to identify and explore the future areas of collaboration between the two countries.

1. INTRODUCTION

As members of the Commonwealth, India and Australia have a shared history and language, common democratic traditions, similar legal, financial and Governmental structures and common interest as Indian Ocean littoral states. With the increasing importance of the Asia-Pacific region, there are concerted efforts on both sides to expand and diversify bilateral relations. However, Australian reaction to our nuclear tests in 1998 caused a setback to our relations. The relations are now back in track and have acquired a new momentum and vigour.

On economic front, India and Australia relations are expanding rapidly. Efforts to promote bilateral trade have been institutionalised by the establishment of the Joint Ministerial Commission (JMC) and the Joint Business Council (JBC). India and Australia have also established a Joint Working Group on Natural Textiles Fibres (1999) and Joint Working Group on Energy and Minerals (1999). The Australia-Business Council conducts a number of programs

designed to promote bilateral business links. The two-way trade figure stands at $2.8 billion (Australian dollar) in 2000-2001, which represents an increase of more than 300 per cent over the last decade.. However, the trade is heavily balanced in Australia's favour as India accounts for 1.7% of Australia's exports, 0.6% of its imports and less than 1% of Australian FDI overseas. India's exports to Australia have so far been in traditional areas like spices, textiles, clothing, footwear, gems and jewellery, chemicals and metals. Australian companies have also been able to demonstrate excellence and technological proficiency in exporting a range of goods and services, such as in the IT, telecommunications, financial and health sectors, manufactured products. The Australian Government has embarked upon a conscious strategy to assist Australian companies trade and invest in India. Austrade is focussing on five key industry sectors – automotive components, agribusiness, infrastructure, IT, and mining - each with its own business program, designed to increase awareness of Australian industry capability in India, and introduce Indian business opportunities to Australian companies. The total value of approved Australian investments in India during August 1991 to August 2001 was A$ 2903, accounting 2.5% of the total approved investments from all countries. The number of Australian joint ventures in India has grown significantly, particularly since 1991 when the process of economic liberalisation was instituted. The number of joint ventures that were approved during the period August 1991 to August 2001 was 404., of these 266 collaborations were financial and 141 technical. Many Indian IT companies have entered Australia, such as NIIT, HCL, TCS, Pentasoft, Satyam, Wipro, Infosys, Aptech, Worlwide, etc. Some other Indian companies working in Australia are Dastur Engineering International, Oberoi Hotels, Asian Patents, Sterlite Industries, etc..

2. INDIAN SCIENTIFIC AND TECHNOLOGICAL COOPERATION

International scientific collaboration is being realized as an important instrument for enhancing the scientific capacity of nations. It takes a number of forms, including sharing of research data, joint experimentation, conferencing, building of databases, standard setting, equipment sharing, etc. The scientists collaborate with their international counterparts for reasons that go beyond scientific compatibility and complementarity. Among these factors are geographical proximity, history, common language, specific problems and issues of common interest, support available economic factors, expertise and research equipment, and laboratories facilities.

Indian international S&T cooperation programmes may be broadly classified into three categories, based on the mode of funding and relative scientific and technical strengths of collaborating partners. The first two categories relate to whether India is a beneficiary or benefactor. India receives grants and some of the advanced countries provide support to science, generally from the local intellectual and natural resources. As a donor, India funds R&D in other countries as a gesture of goodwill and provides consulting services. In the third category, the programmes are implemented on the sharing basis[1].

At the official level, S&T collaboration between India and Australia is starting to take off. A memorandum of understanding in science and technology between the two nations was signed earlier during 1986 and 1975. Most of the collaborations between India and Australia are taking place through inter-institutional agreements at the agency and institutional level or through informal collaborations among scientists. For example, Council of Scientific and Industrial Research, New Delhi has collaboration with Australian Department of Industry, Science and Tourism in a few research projects of industrial importance. Similarly, India and Australia

signed an agreement for collaboration with Australia in agricultural research and development in February 1996. Under this agreement, ICAR-ACIAR collaborative projects were undertaken in the disciplines of crops, soil and water management, and animal sciences. Similarly, the Department of Space of Government of India has an agreement with its counterpart in Australia for peaceful uses of space research[2].

As a part of the scientific support, the Australian government offers few scholarships to Indian students to study at the postgraduate and doctoral level at Australian universities. A large number of Indian students go to Australia for higher and professional studies. In 1994-95 about 370 Indian students were granted visas, but this number crossed 12, 000 mark during 2001. On an average 5000 to 6000 students go every year[3]. At present, nearly 10, 000 students are currently enrolled in Australian universities and technical institutes. Australia has a big infrastructure consisting of 39 universities and 250 technical and vocational institutes. These institutions have close linkages with educational institutions from USA, UK, Canada, Europe and Asia. Australia offers internationally recognised education and training with a very strong practical base.

The S&Tcollaboration between India and Australia leads to different kinds of output such as joint research papers, technology transfer, joint development of products, etc. The outcome of joint collaborative research is not really documented in literature sources. To gauge the outcome of collaborative research is very difficult. However, the co-authored papers resulting from the collaborations give some idea about the extent, mode and direction of collaborative research between these two nations in science and technology. An exercise has, therefore, been undertaken to study the extent of collaboration between India and Australia, the areas of collaborative research priorities, the nature of research collaboration, and the collaboration linkages between their institutions.

3. RESEARCH PRIORITIES

In India, the priority areas of research, as reflected in distribution of papers are chemistry, physics, biomedical research, clinical medicine, and engineering and technology. The publications output from 1986-88 to 1995-97 increased from 25.7% to 27.3% in chemistry, 16.2% to 20.2% in physics, and 10.8% to 11.1% in engineering & technology. For the corresponding period, the publication output decreased from 15.1% to 13.6% in biomedical research and 12.6% to 12.3% in clinical medicine. The other disciplines receiving lesser priority during 1995-97 were biology (7%), earth & space sciences (4.9%) and mathematics (1.1%)[4].

The share of internationally co-authored papers in the Indian research output has increased from 9.5% during 1986-88 to 15.7% during 1995-97. In chemistry, its share has increased from 6.1% in 1986-88 to 10.0% in 1995-97. The increase registered during the corresponding period was from 12.9% to 22.8% in physics, 10.3% to 13.5% in engineering and technology, 10.8% to 16.9% in biology, and 13.8% to 25.2% in earth space sciences. In terms of national research priorities in Australia clinical medicine continues to receive highest priority amongst all disciplines. Its share in total publications output remained almost the same 29.6% from 1986-88 to 1995-97. The other disciplines receiving higher priority in Australia during 1995-97 were biology (15.5%), biomedical research (13.0%), physics (8.9%), chemistry (8.4%) earth & space sciences (6.7%) and engineering & technology (5.6%)[4].

The share of internationally co-authored papers in the Australian publications output increased from 16.4% during 1986-88 to 27.6% during 1995-97. In clinical medicine, its share of internationally co-authored papers rose from 11.5% during 1986-88 to 21.9% during 1995-97. The increase registered in the percentage share of internationally co-authored papers during the same period for other disciplines was from 13.7% to 21.2% in biology, 19.8% to 32.1% in biomedical research, 19.8% to 37.7% in physics, 18.2% to 27.5% in chemistry, 28.9% to 46.4% in

earth & space sciences, and 19.5% to 27.7% in engineering & technology, etc[4].

4. OVERALL PROFILE OF COLLABORATION

India's international collaboration in S&T has shown increasing trend over the years. India was collaborating with 86 countries during 1986-88, which increased to 109 countries during 1995-97. Against this, Australia's international collaboration with different countries increased from 84 to 126 countries during the same period. India's research interest in Australian institutions for collaboration is increasing over the years. The Australian's share in India's International co-authored papers has increased from 2.6% during 1986-88 to 2.9% during 1995-97. In contrast Australia's has accorded less priority to India in its internationally co-authored papers. India's share in Australia's internationally co-authored papers has decreased from 1.3% during 1986-88 to 1.1. % during 1995-97 4

5. OBJECTIVES

The aim of this paper is to study the research collaborations of India with Australia, using joint co-authored publications data. The main objectives were: (i) To study the nature of Indian collaboration in S&T with Australia; (ii) To identify the broad subject areas of these collaborations, (iii) To study the impact of these collaborative research efforts in different fields of S&T, and (iv) To identify the major institutions in India and Australia involved in these collaborative research programs.

6. METHODOLOGY

The data for the study consisted of joint publications resulted from India's collaboration with Australia. These co-authored publications were derived from CD-ROM version of the international database, *Science Citation Index* (SCI), for a period of five years, from 1995 to 1999. The articles were classified under 10 major disciplines and 58 sub-disciplines, according to a scheme suggested by Computer Horizon Inc. (CHI), USA. Each article is classified into a main discipline and a sub-discipline using the subject classification of the title of the journal in which it was published. The nature of the collaboration was defined as bilateral and multilateral, depending upon the number of countries participating in it, as reflected in the affiliations of the authors. A research paper was considered to indicate (i) bilateral collaboration, when there was participation of only two countries, one India and with Australia, and (ii) multilateral collaboration, when the participation was of three or more countries, including India, Australia, and other countries. The impact factor (IF) referred in this study was taken from the *Journal Citation Report* (ISI, USA), published annually. The IF is the measure of citation frequency of any paper on an average in any journal for a particular year. IF may be defined as the mean number of citations to papers published in the journal in the preceding two years and is available for approximately 5500 journals covered in SCI database annually.

7. RESULTS AND DISCUSSION

7.1 Distribution of S&T Papers by Nature of Collaboration

As a result of collaboration between Indian and Australian scientists from 1995 to 1999, a total of 322 co-authored papers in S&T were reported in *Science Citation Index* (SCI) database. Thus, on an average there were 64 co-authored publications per year. There was however, no systematic growth of co-authored publications during the period; although a sudden jump was observed after 1997. Of the total co-authored publications, 62.11% (200 papers) were bilateral in nature, i.e. those involved the participation of Indian and Australian scientists. The remaining 37.89% (122 papers) were multilateral in nature, i.e. involving the participation of more than two countries, i.e participation of other countries along with India and Australia as institutional authors (Table 1).

Table 1: Distribution of Indo–Austrian co-authored papers by nature of collaboration

Year	No. of co-authored papers		
	Bilateral	Multilateral	Total
1995	32	21	53
1996	35	19	54
1997	34	18	52
1998	47	35	82
1999	52	29	81
Total	**200**	**122**	**322**

7.2 Distribution of S&T co-authored papers by the type of publications

Of the 322 co-authored publications during 1995-99, 282 papers appeared as journal articles, 21 as meeting abstracts, 10 as letters, 5 as reviews, 2 as editorial-material and 1 each as note and correction.

7.3 Distribution of Co-Authored S&T Papers by Disciplines/ Sub-Disciplines

7.3.1 Disciplines

The co-authored papers have been classified under 10 major fields and 58 sub-fields. The distribution of 322 co-authored papers has been skewed towards Clinical Medicine, Chemistry, Physics, and Earth & Space Sciences, and they together contributed 72.98% of the total papers. The Biology, Engineering & Technology and Biomedical Research together contributed 23.60% of the total papers (Table 2).

It has been observed that the collaborative research was predominately-taking place through bilateral efforts in Chemistry, Biology and Engineering & Technology. Bilateral papers accounted for 88.52%, 83.33%, and 76.92% of the total co-authored papers in these three disciplines. The share of bilateral and multilateral co-authored papers was quite close in Clinical Medicine, Physics, Earth & Space Sciences, and Biomedical Research (Table 2).

Table 2: Distribution of Indo–Australian S&T co-authored papers by discipline

Disciplines	No. of co-authored papers		
	Bilateral	Multilateral	Total
Clinical Medicine	40	30	70
Chemistry	54	7	61
Physics	23	30	53
Earth & Space Sciences	21	30	51
Biology	25	5	30
Engineering & Technology	20	6	26
Biomedical Research	9	11	20
Multidisciplinary Science	6	2	8
Psychology	1	1	2
Social Sciences	1	-	1
Total	**200**	**122**	**322**

7.3.2 Sub- Disciplines

The distribution of co-authored papers in each discipline into its various sub-disciplines was also studied. The results are discussed as follows:

(a) Clinical Medicine

The 70 co-authored papers in Clinical Medicine are scattered across 21 sub-disciplines, with major focus on ophthalmology (24 papers), general & internal medicine (12 papers), cardiology (5 papers) and endocrinology (4 papers). Eight sub-disciplines had contributed 2 papers each and 9 sub-disciplines only one paper each. Among the 12 sub-disciplines contributing 2 or more papers, the research was predominantly bilateral in ophthalmology, endocrinology, and pathology and multilateral in general & internal medicine, cardiology, environment and occupational health, and fertility.

(b) Chemistry

The 61 co-authored papers in Chemistry are scattered across 6 sub-disciplines. The focus was on two sub-fields, physical

chemistry and general chemistry, accounting for 42.62%, and 27.86% of the total chemistry output respectively. Next in priority was inorganic & nuclear chemistry and organic chemistry, accounting together for 26.22% of the total output. The research was predominately bilateral in all sub-fields, except in organic chemistry, where there was equal contribution of bilateral and multilateral research papers.

(c) Physics

The 53 papers in Physics are scattered across 7 sub-fields, the major focus was on general physics, nuclear & particle physics, applied physics and optics accounting for 30.18%, 30.18%, 18.86% and 13.20% of the total physics output, respectively. The research was predominantly bilateral in optics, solid-state physics and chemical physics, and multilateral in nuclear & particle physics, applied physics and fluids & plasma research.

(d) Earth & Space Sciences

The distribution of 51 co-authored papers in Earth & Space Sciences under 6 sub-fields was highly skewed towards astronomy & astrophysics and earth & planetary science, and they accounts for 60.78% and 25.49% of the total papers in this field, respectively. The research was predominantly bilateral in geology and environment science, and multilateral in earth & planetary science, oceanography & limnology, and meteorology & atmospheric physics.

(e) Biology

The 30 papers in Biology are scattered in three sub-fields: agricultural & food sciences (19 papers, 63.33%), botany (10 papers, 33.33%) and ecology (1 paper, 3.33%). The research was predominately bilateral in all the three sub-fields.

(f) Engineering & Technology

The 26 co-authored papers in Engineering & Technology are scattered across 8 sub-disciplines. The research was predominately bilateral in aerospace technology, metals & metallurgy, material science, computers and mechanical engineering and multilateral in civil engineering.

(g) Biomedical research

The 20 co-authored papers in Biomedical Research are scattered in 7 sub-disciplines. The major focus was on genetics & heredity and microbiology, contributing 30% each out of its total output. The research was predominately bilateral in parasitology and multilateral in virology, nutrition & diet, and cell biology cytology & history sub-fields.

7.4 Distribution of S&T Co-Authored Papers by Impact Factor

The impact of co-authored papers was assessed through the impact factor of the reporting journals where such joint research was reported. The impact factor of co-authored papers varied from 0.06 and 39. The average impact factor of the all co-authored papers has been worked out to be 2.60; it was 2.52 for bilateral papers and 2.73 for multilateral papers.

Around 36% of the multilateral papers had impact factor 2.5 and above. The quality of bilateral research output, on the other hand, is comparatively low, as only 24.5% of papers had impact factor 2.5 and above.

Table 3: Range of Impact factor of Indo–Australian co-authored S&T papers

Range of Impact Factor (IF)	No. of Indo–Australian co-authored S&T papers		
	Bilateral	Multilateral	Total
0.0 – 0.49	29	10	39
0.5 – 0.99	60	21	81
1.0 – 1.49	37	14	51
1.5 – 1.99	15	14	29
2.0 – 2.49	7	16	23
2.5 – 2.99	17	10	27
3.0 – 3.49	6	14	20
3.5 – 3.99	3	8	11
4.0 – 4.99	11	2	13
5.0 – 5.99	7	-	7
6.0 – 6.99	1	2	3

7 and above	3	6	9
Total	**196**	**117**	**313**

The average impact of Indo–Australian co–authored papers varied from discipline to discipline, over a long range, from 0.34 to 23.56. The average impact factor of multilateral papers was higher in Physics, Earth & Space Sciences, and Multidisciplinary Science, while it was comparatively lower in Chemistry, Biology, Engineering & Technology, Biomedical research and Psychology. In Clinical Medicine and Biology, the average impact factor of both bilateral and multilateral papers was very close. In Multidisciplinary Science, Biomedical Research and Chemistry papers, there was comparatively wider gap between the average impact factor of bilateral and multilateral papers.

Table 4: Average impact factor of Indo–Australian S&T co-authored papers by disciplines

Subject	Impact factor per paper		
	Bilateral	**Multilateral**	**Total**
Chemistry	3.55	1.75	3.35
Physics	1.42	1.81	1.63
Biology	0.86	0.71	0.84
Engineering & Technology	0.63	0.34	0.57
Biomedical Research	6.95	2.78	4.53
Earth & Space Sciences	1.98	2.48	2.27
Clinical Medicine	3.33	3.34	3.35
Multidisciplin-ary Science	0.61	23.56	6.35
Psychology	2.15	1.90	2.02

7.5 Institutional Participation in Collaborative Research

In all 124 Indian and 76 Australian institutions were involved in the Indo – Australian collaborative research during 1995 to 1999. As is evident from Table 5, as many as 45 Indian and 33 Australian institutions were partners in a team, which produced only 1 paper. On the other hand, as many as 8 Indian and 10 Australian institutions were partners in a team, which produced more than 15 papers.

The research and academic institutions participating from India in 10 and above collaborative papers were: LV Prasad Research Institute, Hyderabad (31 papers), Raman Research Institute, Bangalore (29 papers), ICRISAT (27 papers), N E Hill University Shillong (23 papers), Tata Institute of Fundamental Research, Bombay (19 papers), Indian Institute of Science, Bangalore (17 papers), National Physical Laboratory, New Delhi (16 papers), University of Jammu, Jammu (15 papers); University of Rajasthan, Jaipur (14 papers); and University of Hyderabad, Hyderabad (10 papers).

The research and academic institutions participating from Australia in 10 and above collaborative papers were: University of Syndey, Sydney (71 papers), University of Adelaide (37 papers), University of New South Wales (36 papers); University of Melbourne (34 papers), CSIRO (24 papers), Queens land Department of Primary Industry (23 papers), Australian National University (22 papers), Australian Telescope National Facility, Epping (17 papers), Royal Children's Hospital (21 papers), University of Western Australia (15 papers) and University of Wollongong (14 papers)

8. BILATERAL CO-AUTHORED PAPERS

8.1 Discipline-Wise Distribution of Bilateral Co-Authored Papers

Among 200 Indo–Australian bilateral co-authored papers, the largest number of papers were in chemistry (54 papers, 27%), followed by clinical medicine (40 papers, 20%) biology (25 papers, 12.9%), physics (23 papers, 11.9%) earth & space science (21 papers, 10.9%) and engineering & technology

Table 5: Distribution of co-authored papers & collaborative linkages of Indian and Australian institutions

India		Australia	
No. of co-authored papers	**No. of institutions as team partners**	**No. of co-authored papers**	**No. of institutions as team partners**
1	45	1	33
2	38	2	13
3	12	3	5
4	10	4	3
5	2	5	4
6	2	6	2
7	3	7	2
9	1	8	2
10	1	9	1
14	1	14	1
15	1	15	1
16	1	17	1
17	1	21	1
19	1	22	1
23	1	23	1
27	1	24	1
29	1	34	1
30	1	37	1
31	1	71	1
Total	**124**	**Total**	**76**

(20 papers, 10%). The contribution of other fields was small, less than 5%.

8.2 Sub-Discipline Wise Distribution of Bilateral Co-Authored Papers

The 54 co-authored papers in chemistry were scattered across 6 sub- disciplines with major focus on physical chemistry (24 papers, 44.4%), general chemistry (16 papers, 29.6%), inorganic & nuclear chemistry (8 papers, 14.81%) and organic chemistry (4 papers, 7.4%). In rest of the other two sub-disciplines, there was only 1 co-authored paper each. The 23 co-authored papers in physics were scattered across 6 sub-disciplines with major focus on general physics (8 papers, 34.8%), optics (7 papers, 30.4%) and applied physics (4 papers, 17.4%). The 21 co-authored papers in earth & space science were scattered in 4 sub disciplines, with major focus on astronomy & astrophysics (14 papers 66.7%), earth & planetary sciences and geology (3 papers each, 14.3%). The 20 co-authored papers in engineering & technology were scattered across 7 sub disciplines, with major focus on metals & metallurgy (6 papers, 30%), material science (4 papers, 20%), and aerospace technology (3 papers, 15%).

The 40 co-authored in clinical medicine were scattered in 14-sub disciplines, with major focus on ophthalmology (22 papers, 55%), general & internal medicine (3 papers, 7.5%) and pathology (2 papers, 5%). In remaining 11 sub-disciplines, there was only one co-authored paper each. The 25

co-authored papers in biology were scattered across only 3 sub-disciplines, with major focus on agriculture & food science (16 papers, 64%), and botany (8 papers, 32%).

8.3 Impact Factor per Bilateral Co-Authored Paper

The highest average impact factor per bilateral co-authored paper was 6.95 in Biomedical Research, followed by 3.55 in Chemistry, 3.33 in Clinical Medicine, 2.15 in Psychology, 1.98 in Earth & Space Sciences, 1.42 in Physics, 0.86 in Biology, 0.63 in Engineering & Technology and 0.61 in Multidisciplinary Science. The sub-disciplines having impact factor above the average impact factor of the their main fields were: general & internal medicine (7.80), ophthalmology (3.70) pathology (3.93), general chemistry (3.60), general physics (1.87), nuclear & particle physics (2.11), chemical physics (2.26) solid state physics (1.96), botany (1.15), aerospace technology (0.66), material science (0.74), computers (1.61), genetics & heredity (14.94), and astronomy & astrophysics (2.22).

8.4 Average Institutional Participation per Bilateral Co-Authored Paper

To find the extent of simultaneous participation of Indian and Australian institutions, each co-authored paper was studied. In 144 co-authored papers (out of 200), one Indian and one Australian institution formed the combination. There was combination of one Indian and two Australian institutions in 27 papers, one Indian and 3 Australian institutions in 6 papers, 1 Indian and 4 Australian institutions in 12 papers, and 3 Indian and 1 Australian institution in 2 papers. There were only 6 papers, where there was a team combination of 2 or more Indian and Australian institutions. The average participation of Indian institutions in these bilateral co-authored papers was 1.110 and that of Australian institutions, 1.225.

Table 6: Simultaneous institutional participation of Indian and Australian Institutions per paper

Number of institutions participating from		No. of co-authored papers
India	Australia	
1	1	144
1	2	27
1	3	6
1	4	3
2	1	12
2	2	5
2	3	1
3	1	2
Total		**200**

8.5 Lead Country in Bilateral Co-Authored Papers

To get an idea about the lead country in the bilateral co-authored paper, the first institutional affiliation under the address field of co-authored papers was examined. In 104 bilateral co-authored papers, Australia was the lead country, while in the remaining 96, it was India.

Table 7. Lead country in Indo-Australian co-authored bilateral papers

Year	No. of papers from the lead country		Total papers
	India	Australia	
1995	15	17	32
1996	13	22	35
1997	21	13	34
1998	20	27	47
1999	27	25	52
Total	**96**	**104**	**200**

8.6 Strength of Collaboration Among Pair of Institutions

To find out the strength of bilateral collaboration, co-authored papers were studied in terms of fixed papers of institutions from India and Australia. It had been observed that most of the pairs co-authored

only one bilateral paper indicating short- term weak strength. The ones, which co-authored 2 to 12 papers, indicating long-term strong strength were:

(a) North East Hill University Department of Chemistry, Shillong, India and University of Adelaide, Department of Chemistry, Adelaide, SA (12 papers)

(b) LV Prasad Eye Institute, Hyderabad and University of New South Wales, CRCERT, Sydney (11 papers)

(c) LV Prasad Eye Institute, Hyderabad and University of Melbourne, Centre of Eye Research, Melbourne (10 papers)

(d) Raman Research Institute, Bangalore and University of Sydney, School of Physics, Sydney (8 papers).

(e) Punjab University, Department of Chemistry, Chandigarh and University of Western Australia, Department of Chemistry, Ned lands, WA (8 papers).

(f) Raman Research Institute, Bangalore and University of Tasmania Department of Physics, TAS (5 papers)

(g) Raman Research Institute Bangalore and Australian Telescope National Facility, Epping, NSW (6 papers).

(h) National Physical Laboratory New Delhi and University of Wollongong, Institute of Superconductivity Electronic Materials, Wollongong (4 papers).

(i) LV Prasad Eye Institute, Hyderabad and University of New South Wales, School of Optometry, Contact Lens Research Unit, Sydney (4 papers)

(j) University of Hyderabad School of Physics, Hyderabad and University of Queens land, Department of Physics, St-Lucia (4 papers)]

(k) Punjab University, Department of Chemistry, Chandigarh and University of Adelaide, Department of Chemistry, Adelaide (3 papers)

(l) University of Hyderabad, School of Chemistry, Hyderabad and University of New South Wales, School of Chemistry, Kensington (3 papers)

(m) Indian Institute of Technology, Department of Metallurgy and Material Engineering Kanpur and University of Wollongong, Department of Material Engineering, Wollongong (2 papers).

9. MULTILATERAL CO-AUTHORED PAPERS

In all there were 122 multilateral co-authored papers resulting from collaboration of other countries, with participation of India and Australia in all of them.

9.1 Discipline-Wise Distribution of Multilateral Co-Authored Papers

The distribution of 122 multilateral co-authored papers by disciplines in order of number of publications was: clinical medicine, physics and earth & space sciences (30 papers each, 24.59% each), biomedical research (11 papers, 9.01%), chemistry (7 papers, 5.74%), engineering & technology (6 papers, 4.92%), and biology (5 papers, 4.09%).

9.2 Sub-Discipline Wise Distribution of Multilateral Co-Authored Papers

The 30 multilateral co-authored papers in clinical medicine were spread over 13 sub-disciplines, with focus on general & internal medicines (9 papers 30%), cardiology (5 papers, 16.66%) and ophthalmology, environment & occupational health, and fertility (2 papers each, 6.66% each). The 30 co-authored papers in physics were spread over 4 sub-disciplines, with focus on nuclear & particle physics (14 papers, 46.66%), general physics (8 papers, 26.66%) and applied physics (6 papers, 20%). The 30 co-authored papers in earth & space sciences were spread over 4 sub-disciplines, with major focus on astronomy & astrophysics (17 papers, 56.66%) and earth & planetary sciences (10 papers, 33.33%). The 11 co-authored papers in biomedical research were in 6 sub-disciplines, with focus on

genetics & heredity and microbiology (3 papers each, 27.27% each) and nutrition & dietet (2 papers, 18.18%). The 6 co-authored papers in engineering & technology were in 6 sub-disciplines, with focus on chemical engineering (2 papers, 33.33%). The 5 co-authored papers in biology were distributed in two sub-disciplines: agricultural and food science (3 papers, 60%) and botany (2 papers, 40%)

9.3 Impact Factor Per Multilateral Co-Authored Paper

The disciplines ranked according to average impact factor as: Multi-disciplinary Sciences (23.56), followed by Clinical Medicine (3.34), Biomedical Research (2.78), Earth & Space Sciences (2.48), Psychology (1.90), Physics (1.75), Chemistry (1.75), Biology (0.71) and Engineering & Technology (0.34).The sub-disciplines having impact factor above the average impact factor of their main fields were: general & internal medicine (5.49), psychiatry (3.50), allergy (4.64), nuclear & particle physics (2.31), fluid & plasmas (1.89), botany (0.96), aerospace technology (0.58), genetics & heredity (5.05), microbiology (2.97), astronomy & astrophysics (2.84), geology (2.58), meteorology & atmospheric physics (4.24), organic chemistry (1.87), general chemistry (1.97), and physical chemistry (2.20).

9.4 Distribution of Multilateral Co-Authored Papers by Country of Participation

Multilateral co-authored papers involved the participation of 67 other countries, besides India and Australia. These countries collaborate among themselves in different fields and in different combinations involving simultaneous participation of countries, varying from 3 to 29 countries. The groups formed by participation of 11 to 29 countries accounted for 23.77% and those comprising 3 to 5 countries accounted for 55.74% of the total co-authored papers (Table 8)

Table 8: Participation of countries in multilateral co-authored papers

No. of countries participating	No. of co-authored papers
3	45
4	13
5	10
6	2
7	5
8	7
9	5
10	6
11	9
12	6
13	8
14	2
15	2
17	1
29	1
Total	**122**

9.5 Lead Country in Multilateral Co-Authored Papers

The scientists coordinating the multilateral projects are likely to be lead authors in research output from these projects and the countries they represent are known as lead countries. They were identified by the first institutional affiliation in multilateral papers. Australia topped the list of multilateral co-authored papers with lead in 30 papers. The USA was the lead country in 19 papers while India was the first author in 16 papers. The UK and Russia was the lead country in 10 and 9 papers each. These lead countries accounted together 68.85% of all multilateral co-authored papers (Table 9).

Table 9. Lead countries in multilateral co-authored papers

Name of country	No. of published papers
Australia	30
USA	19
India	16
UK	10
Russia	9
New Zealand	7

Kazakhstan	6
Switzerland	5
China	1
Frances	4
Germany	3
Brazil	3
Canada	2
Austria	1
South Africa	1
Italy	1
Japan	1
Belgium	1
S .Arabia	1
Total	**122**

9.6 Extent of Participation by Other Countries in Multilateral Co-Authored Papers

The USA had the largest participation along with India and Australia in 78 multilateral co-authored papers. The participation by Germany, China, UK, France, Sweden and Brazil was followed with 33, 28, 25, 24, and 21 co-authored papers, respectively. There were 27 countries, which had the participation in only 1 and 2 co-authored papers.

Table 10. Extent of participation by other countries in multilateral co-authored papers

No. of papers	No. of other countries
78	1
37	1
33	1
28	1
25	1
24	1
21	1
18	1
16	1
14	2
13	4
12	1
11	2
10	2
9	1
7	1
6	3
5	5
4	4
3	6
2	14
1	13
Total	**67**

Table 11. Participation by institutions in multilateral co-authored papers

No. of participating institutions	No. of published papers
3-5	57
6-10	18
11-15	14
16-20	17
21-24	11
26-30	1
66-70	1
Total	**122**

9.7 Distribution of Papers by Participating Institutions

Different types of organizations from 69 countries have collaborated in various groups in multilateral co-authored papers. These ranged from 3 to 69 institutions. The group formed with participation of 3 to 10 institutions accounted for 61.47% of the total multilateral output. The group involving participation of 21 to 69 institutions accounted for 13.11% of all multilateral co-authored papers.

9.8 Strength of Collaboration Among Pair of Institutions in Multilateral Papers

The strength of collaboration through multilateral channels was studied among Indian and Australian institutions. Most of the pairs of institutions from both countries had

co-authored one paper each. The ones, which co-authored 2 to 15 papers were:

(a) Punjab University, Department of Physics, Chandigarh and University of Sydney, School of Physics, Sydney (15 papers)

(b) University of Rajasthan; Department of Physics, Jaipur and University of Sydney, Department of Physics, Sydney (15 papers)

(c) University of Jammu, Department of Physics, Jammu and University of Sydney, Department of Physics, Sydney (15 papers)

(d) Raman Research Institute, Bangalore and Australian Telescope National Facility, Epping, NSW (5 papers)

(e) National Physical Laboratory, New Delhi and IPS Radio & Space Service, W-Chattswood (3 papers)

(f) National Physical Laboratory, New Delhi and University of Wollongong, Institute of Superconductivity & Electronic Materials (Wollongong (3 papers)

(g) Tata Institute of Fundamental Research, Pune Campus and Australian-Telescope National Facility, Epping (3 papers)

(h) Tata Institute of Fundamental Research Bombay and University of Wollongong Institute of Superconductivity and Electronic Materials, Wollongong (3 papers)

(i) Tata Institute of Fundamental Research, Pune Campus and University of Sydney School of Physics, Sydney (2 papers)

(j) North East Hill University, Shillong and University of Adelaide Department of Chemistry, Adelaide (1/2 papers)

(k) North East Hill University, Shillong and Australian National University, Melbourne (2 papers)

(l) North East Hill University, Shillong and University of Sydney, School of Physics, Sydney (2 papers)

10. RESULTS AND CONCLUSION

The S&T collaboration between India and Australia mainly took place through bilateral efforts and accounted for 62.11% of the total collaborated papers. Clinical medicine, chemistry, physics and earth & space sciences were the priority areas for collaborative research, accounting for 21.74%. 18.94%, 16.46% and 15.84% respectively of the total collaborated papers.

The joint research under broad disciplines was highly scattered across various sub-disciplines: 70 co-authored papers in 21 sub-disciplines were under clinical medicine; 61 co-authored papers in 6 sub-disciplines were under chemistry; 53 co-authored papers in 7 sub-disciplines under physics; 51 co-authored papers in 6 sub-disciplines under earth & space sciences; 30 co-authored papers (3 sub-disciplines) under biology; 26 co-authored papers (8 sub-disciplines) under engineering & technology; and 20 co-authored papers (7 sub-disciplines) under biomedical research.

The focus of joint research under sub-disciplines was in the following order: ophthalmology (34.28%) and general & internal medicine (17.14%) under Clinical Medicine; physical chemistry (42.62%) and general chemistry (27.86%) under Chemistry; general physics (30.18%), nuclear & particle physics (30.18%), applied physics (18.86%) and optics (13.30%) under Physics; astronomy & astrophysics (60.78%) and earth & planetary sciences (25.49%) under Earth & Space Sciences; agriculture & food science (63.33%) and botany (33.33%) under Biology; and genetics& heredity (30%) and microbiology (30%) under Biomedical Research.

The priorities assigned to different subject fields had different emphasis under bilateral and multilateral research. Under bilateral research, Chemistry, Clinical Medicine and Biology are the priority areas, accounting for 27% 20% and 12.5%, respectively of the total joint bilateral co-authored research output. Under multilateral research, Clinical Medicine, Physics and Earth & Space Sciences were the priority areas, accounting for 24.59% each of the total multilateral collaborative output.

There were 67 other countries, which participated along with India and Australia in joint multilateral papers. The United States had the largest participation through 78 such co-authored papers, followed by Germany (37), China (33), England (28), France (25), Sweden (24) and Brazil (21). A group of institutions ranging from 3 to 10 accounted for 62% of all multilateral co-authored papers. The group involving 21 to 69 institutions accounted for 13% of multilateral co-authored papers. The strongest collaboration under multilateral research was among the following Indian and Australian

On comparing the quantum of bilateral and multilateral research in each broad discipline, it was observed that the collaborative research was taking place through bilateral efforts in Chemistry, Biology and Engineering & Technology. The bilateral papers accounted for 88.52%, 83.33%, and 76.92% respectively of the total co-authored papers in these three disciplines. The share of bilateral and multilateral co-authored papers was comparatively closer in Biomedical Research, Clinical medicine, Physics, and Earth & Space Sciences.

The average impact factor of all co-authored research papers was 2.60. The average impact factor of bilateral and multilateral co-authored research output was 2.52 and 2.73. Compared to multilateral research, the quality of bilateral research was low, as only 24.49% of the papers had impact factor about 2.5 and above. In contrast, 36% of the papers under multilateral research had the impact factor 2.5 and above.

Under bilateral research output, Biomedical Research, having impact factor per paper as 6.95, achieved the largest impact factor. This was followed by Chemistry with impact factor as 3.55, Clinical Medicine (3.33), Psychology (2.15), Earth and Space Sciences (1.98), Physics (1.42), Biology (0.86), Engineering & Technology (0.63) and Multidisciplinary Science (0.61). The sub disciplines having impact factor above the average impact factor of the their main fields were: general & internal medicine with impact factor 7.80, ophthalmology (3.70), pathology (3.93), general chemistry (3.60), general physics (1.87), nuclear & particle physics (2.11), chemical physics (2.26), solid state physics (1.96), botany (1.15), aerospace technology (0.66), material science (0.74), computers (1.61), genetics & heredity (14.94), and astronomy & astrophysics (2.22).

Under multilateral research, comparatively higher impact had been revealed by papers in multidisciplinary sciences with an average impact factor 23.56, followed by Clinical Medicine (3.34), Biomedical Research (2.78), Earth & Space Sciences (2.48), Psychology (1.90), Physics (1.75), Chemistry (1.75), Biology (0.71) and Engineering & Technology (0.34).The sub-disciplines revealing impact above the average impact of their main fields were: general & internal medicine (5.49), psychiatry (3.50), allergy (4.64), nuclear & particle physics (2.31), fluid & plasmas (1.89), botany (0.96), aerospace technology (0.58), genetics & heredity (5.05), microbiology (2.97), astronomy & astrophysics (2.84), geology (2.58), meteorology & atmospheric physics (4.24), organic chemistry (1.87), general chemistry (1.97), and physical chemistry (2.20).

A total of 124 Indian and 76 Australian institutions were involved in joint collaborative research during the period under study. The collaboration was not really strong in terms of number of institutions simultaneously participating in each co-authored paper. However, there were 15 co-authored papers, where there was participation of 8 Indian and 10 Australian institutions as a team in each paper. Under bilateral research, the strongest collaboration was between North East Hill University, Department of Chemistry, Shillong, India and University of Adelaide, Department of Chemistry, Adelaide, SA; LV Prasad Eye Institute, Hyderabad and University of New South Wales, CRCERT, Sydney; LV Prasad Eye Institute, Hyderabad and University of Melbourne, Centre of Eye Research, Melbourne (10 papers); and Raman Research Institute, Bangalore and University of Sydney, School of Physics, Sydney (8 papers) resulting in the publication of 12, 11, 10 and 8 joint co-authored papers, respectively.

institutions: Punjab University, Department of Physics, Chandigarh and University of Sydney, School of Physics, Sydney; University of Rajasthan; Department of Physics, Jaipur and University of Sydney, Department of Physics, Sydney; and University of Jammu, Department of Physics, Jammu and University of Sydney, Department of Physics, Sydney resulting in 15 joint co-authored papers, respectively.

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