

India's Collaboration with Latin America as Reflected in Co-authored Papers

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Abstract

India's relations with the Latin American countries have been traditionally friendly and interaction with them is close both at bilateral and multilateral level. India's collaboration with Latin American countries has resulted in different kinds of outputs, including joint publications, technology development, technology transfer, improvised products and processes. The joint research output emanating out of research collaboration is an important source of information for mapping India's collaboration with Latin America, and its impact on different fields. This paper attempts to study the research collaboration of India with Latin America, with the following objectives: (i) To study the nature of Indian collaboration with Latin American countries in S&T, as reflected in co-authored research papers, (ii) To identify the specific subject areas of Indian collaboration with Latin America, (iii) To study the impact of Indian collaborative research with Latin America in different fields, and (iv) To identify the major Indian institutions involved in this collaborative research with institutions in Latin America.

1. INTRODUCTION

India's relations with the Latin American countries (LAC) have been traditionally friendly and interaction with them is close both at bilateral and multilateral level. High-level visits complemented by official and exchange visits have further cemented India's relations with the region. In the economic field a concentrated effort has been made to enhance bilateral co-operation. As a result, India has trade and economic agreements with seven Latin American countries and has set up 'joint business councils' with some other countries of the region. In continuation of her 'Focus LAC' Programme, Indian exhibitions and joint seminars are organised to discuss and explore the potential of mutual interactions. India enjoys considerable goodwill in the LAC region. At the institutional level, there are cultural, educational and scientific exchange programmes that provide the framework for meaningful co-operation

and interaction between academicians, scholars and scientists. India also provides technical assistance under its ITEC programme to several countries of the region.

2. S&T COLLABORATION BETWEEN INDIA AND LATIN AMERICA

The environment surrounding science and technology world over is changing rapidly with the emergence of a new world economic order, and which is based on competition, co-operation, and globalisation. The international co-operation is becoming an important policy. Recognising the importance of international co-operation in science and technology, the Government of India had started collaboration in scientific and technological fields both at bilateral and multilateral levels with number of developed and developing countries.

Such international collaborations help in the development of science and technology capabilities of both the participating countries in one way or the other. There is a wide scope of collaboration between India and Latin American countries, whereby the participating countries can mutually share each other's expertise in the S&T knowledge-base. At present, India's collaboration with Latin America is being undertaken through bilateral and multilateral agreements in science and technology¹. Among bilateral collaborations, India and Latin America have taken few initiatives, which are described below. They are also participating in a number of multilateral projects undertaken under the umbrella of international co-operation, through United Nations agencies, such as UNESCO, ILO, WHO, UNEP, FAO, UNIDO, IAEA and the World Bank.

2.1 India's Collaboration Agreements with Latin America in S&T

The Indian government has established formal co-operative relationships in S&T with Latin American countries in the form of agreements or some other arrangements¹, as described below:

- (a) Brazil**—An Indo-Brazil Committee was established in 1997 in pursuance of the Indo-Brazil Agreement on co-operation in the fields of science and technology signed in July 1985, and the Agenda on S&T co-operation, signed in January 1996. A series of joint workshops have been organised to evolve joint programs in the area of climate research and health sciences. In addition, a number of other MoUs and agreements have been signed between the two countries, some of them are:
- ICAR and EMBRAPA for co-operation in the field of Agriculture, signed in August 1995 at Brasilia.
 - India-Brazil Common Agenda for Environment, signed on 27 January 1996 at New Delhi.

- Bilateral agreement in the area of Health and Medicine, signed on 6 May 1998 at Brasilia
- Ministry of Science & Technology, Brazil and Ministry of Information Technology, India, on collaboration in information technology services and setting up a Task force on information technology, signed on 11 September 2000 at Brasilia
- Co-operation in Space between Brazilian Space Agency and Indian Space Research Organization in the peaceful uses of outer space, signed on 1 March 2002 at Bangalore, and
- Academic exchange and co-operation between Goa University and the Federal University of Rio de Janeiro.

A delegation led by the Prof. Murali Manohar Joshi, Indian Minister of Science and Technology, Government of India, had visited Brazil in July 2001, when a MoU was signed with the Brazilian counterpart on 5 July 2001. The areas covered in this MoU include biotechnology, bioinformatics, human health, climate research, renewable energy, space sciences, marine sciences, new materials and industry-research partnership. Subsequently, India-Brazil Science Council and a Programme Management Board, with six members from each side, were set up in 2002. The first meeting of this Council was organised in New Delhi, at which future perspectives on S&T co-operation between the two countries were discussed and a few projects were identified for joint implementation during the next two years.

- (b) Mexico**— An agreement for co-operation in the fields of S & T between the Government of India and the Government of the United Mexican States was signed in July 1975. This programme of co-operation continued and was renewed in 2000 for a period of three years, up to 2003. The areas identified for co-operation under this programme were: atmospheric sciences, physical sciences, geosciences, seismology, chemical sciences, new materials, computer science and biotechnology. The collaboration is going on through the following modalities: (i) joint

research and development projects, (ii) exchange of specialists, and (iii) organisation of joint symposia, conferences and workshops. Under this collaboration, three joint R&D projects have been carried out between:

- University of Hyderabad and *Universidad Metropolitana* – Izataapalapa,
- Indian Institute of Science, Bangalore and *Nacional Autonoma de Mexico*, and
- Indian Institute of Astrophysics, Bangalore and its counterpart in Mexico.

(c) Cuba—An Indian S&T delegation led by the Secretary, Department of Science and Technology, Government of India, had visited Cuba for the first meeting of the Indo-Cuban Joint Committee on S&T, set up earlier, in the last week of September 1999. A new protocol on co-operation was concluded with Cuba for the period 1999-2000, which envisaged the organisation of two joint workshops and initiation/continuation of 10 joint projects. Under the Indian ITEC and other programmes, about 100 Cuban officials, engineers and scientists have visited India. Four sessions were held of the Indo-Cuban Joint Commission up to 2000 and these have led to active co-operation in the field of agricultural research, non-conventional sources of energy, and some other areas of S&T. An Indo-Cuban Interaction in Biotechnology was also held during 3-5 October 2000 in India.

(d) Peru—The Peruvian President Fujimori visited India in 1997 and President of India, Dr. K.R. Narayanan visited Peru in 1998. During their visits a number of bilateral co-operation agreements were signed between the two countries in the area of Antarctic exploration, agricultural research, space research, and software development. India also offered scholarships for technical training to Peruvian students under its ITEC Program. Indian and Peruvian scientists have already participated in each other's Antarctic expeditions. There had also been bilateral visits for joint research in the fields of

agriculture, space technology, and other high technology areas.

(e) Columbia—The President of Columbia Andres Pastrana Araugo visited India in March 2001. At that time, India had announced the technical training/assistance to be given to Columbia in the area of human resource development in IT, provision of experts, and supply of a solar energy unit. The Minister for Communications & Information Technology, Promod Mahajan, visited Columbia from 31 March 2002 to 3 April 2002. During his visit, a MoU on bilateral co-operation in the field of IT was signed between the two countries.

(f) Argentina—In pursuance of the S&T agreements signed between the India and Argentina, a two member scientific delegation from India had visited Argentina in October 1995. A Programme of co-operation in the fields of Agriculture and Biotechnology was worked out during the visit.

(g) Venezuela—The University of Los Andes had signed a MoU with Jawaharlal Nehru University for exchange of scholars in 1999. The Venezuelan Ministers of Education and Science and Technology had visited India in March 2001. He proposed collaboration with India in the use of IT, biotechnology, etc. The Indian government provides five scholarships to Venezuelans every year for training in India. Ayurveda is becoming popular in Venezuela. There is a proposal for setting a joint Ayurvedic Center in Caracas in the near future.

2.2 Tangible Outputs from S&T Collaborations

India's collaboration with Latin American countries has resulted in different kinds of outputs, including joint publications, technology development, technology transfer, improvised products and processes. The joint research output emanating out of research collaboration is an important source of information for mapping India's collaboration with Latin America, and its impact on different

fields. The present paper makes an assessment in this direction, using the data on joint publications emanating from India's collaboration with Latin American countries.

Some studies have been undertaken in the past on the collaborative linkages of Indian science, using publication data from Science Citation Index (SCI). The study by Nagpaul² was focused on the analysis of transnational linkages of Indian science in eleven scientific fields, with 35 most significant partner countries during 1990 and 1994. The author in collaboration with his colleagues³⁻⁷ has conducted a number of studies analysing India's collaborative linkages, both at bilateral and multilateral level, with Russia, South Asia, South East Asian countries, China, and Australia. The present study also looks at the India's collaboration linkages with Latin American countries.

3. OBJECTIVES OF THE STUDY

The focus of this paper is on the study of research collaboration of India with Latin America, with the following objectives: (i) To study the nature of Indian collaboration with Latin American countries in S&T, as reflected in co-authored research papers, (ii) To identify the specific subject areas of Indian collaboration with Latin America, (iii) To study the impact of Indian collaborative research with Latin America in different fields, and (iv) To identify the major Indian institutions involved in this collaborative research with institutions in Latin America.

4. DATABASE AND METHODOLOGY

The data for the study was derived from the CD-ROM version of the international database, *Science Citation Index* (SCI), for a period of five years from 1996 to 2000. This database covers around 4000 significant journals of the world in all major fields of science and technology. The journals covered by SCI represent the mainstream science. As a result, this study is restricted to co-authored articles generated from India's collaboration with Latin America and published in refereed international journals. The classification of articles has been made in 10 major disciplines and 61 sub-disciplines, according

to a scheme suggested by Computer Horizon Inc. (CHI), USA. Here each article is classified into a main discipline and sub-discipline using the subject classification of the journal in which it is published.

Scientific collaboration was measured through co-authorship of articles, which signify a formal acknowledgement of the joint research. The nature of collaboration, as reflected in the addresses of the authors in a research paper was defined as bilateral and multilateral, depending upon the number of countries participating in it. A research paper was considered to indicate a: (i) bilateral collaboration, when there was a participation of India along with a Latin American country, and (ii) multilateral collaboration, when there was a participation of two or more countries, including India and Latin American countries.

5. RESULTS AND DISCUSSIONS

5.1 S&T Research Output of India and Latin American Countries

Before studying the status of India's collaboration in S&T with Latin American countries, let us have a look at the S&T research output of India and individual Latin American countries, as reflected in the SCI for the period 1991-93 to 2000-02, as shown in Table 1.

It is evident from Table 1 that there existed a wide gap between the average research output of India and Latin American countries. There is a systematic increase in the research output of most of the India and Latin American countries from 1991-93 to 2000-02, except Guatemala and Honduras.

5.2 Research Priorities

The priority areas of research in India, as well as some Latin American countries⁸, as reflected in the publications output of SCI during 1995-97, were as follows:

- (i) **India**—Chemistry (27.3%), Physics (20.2%), Biomedical Research (13.6%), Clinical Medicine (12.3%), and Engineering & Technology (11.1%);
- (ii) **Mexico**—Physics (21.0%), Clinical Medicine (20.2%), Biology (14.8%),

Table 1. Number of scientific and technical articles by country (1991-2002)

Country	Average annual number of articles			
	1991-93	1994-96	1997-99	2000-02
India	10869	11193	11905	13139
Brazil	3809	5188	7944	1058
Argentina	1997	2764	3814	4414
Mexico	1854	2630	3711	4620
Columbia	2035	2204	2240	2490
Chile	1148	1338	1590	2006
Venezuela	561	656	801	860
Cuba	165	245	362	451
Peru	143	149	159	233
Guatemala	64	54	58	62
Honduras	11	15	24	19

Biomedical Research (14.3%), and Chemistry (11.8%);

(iii) **Brazil**—Physics (22.9%), Clinical Medicine (21.7%), Biomedical Research (17.1%), Chemistry (11.6%), and Biology (9.8%);

(iv) **Argentina**—Clinical Medicine (23.6%), Physics (18.4%), Biology (15.5%), Biomedical Research (15.3%), and Chemistry (13.8%);

(v) **Chile**—Clinical Medicine (37.5%), Biomedical Research (13.0%), Chemistry (12.0%), and Biology (11.2%);

(vi) **Venezuela**—Chemistry (19.4%), Clinical Medicine (19.2%), Biomedical Research (14.7%), Physics (14.1%) and Biology (13.3%);

(vii) **Cuba**—Clinical Medicine (26.3%), Physics (15.8%), Chemistry (19.6%), Biomedical Research (15.5%) and Biology (10.6%).

6. INTERNATIONAL COLLABORATION PROFILES OF INDIA AND LATIN AMERICAN COUNTRIES

The size of the India's international collaboration with different countries, as measured through co-authored papers, has been increasing over the years. The share of India's internationally co-authored papers in its research output has increased from 9.5%

in 1986-88 to 15.7% in 1995-97⁸. As against this, the share of international co-authored papers of Latin American countries in their total research output was very high. The country-wise increase of the share of internationally collaborative papers from 1986-88 to 1995-97 was as follows: Brazil—from 28.3% to 41.1%; Mexico—from 30.3% to 42.8%; Chile—from 29.7% to 45.8%; Argentina—from 15.0% to 32.5%; Venezuela—from 33.1% to 45.5%; and Cuba—from 50.7% to 57.5%⁸.

The number of India's collaborative partners has increased from 84 countries in 1986-88 to 109 countries in 1995-97, as reflected in the co-authored papers. As against this, the number of collaborative partners of the Latin American Countries, as seen in co-authored papers, has increased from 66 to 114 for Brazil; 54 to 89 for Mexico; 47 to 77 for Argentina; 42 to 76 for Chile; 37 to 60 for Venezuela; and 29 to 56 for Cuba⁸.

7. INDIA'S COLLABORATION IN S&T WITH LATIN AMERICA

India's collaboration in S & T with Latin American countries in general has been increasing over the years. The increase in the share of the Latin American countries in India's co-authored papers from 1986-88 to 1995-97 was as follows; Brazil—from 0.6% to

2.9%, Mexico—from 0.3% to 1.4%, Argentina—from 0.1% to 0.2%, Chile—from 0.1% to 0.2%, and Venezuela—from 0.1% to 0%. As against this, the priority assigned to India in co-authored papers of Latin American countries has increased in Brazil—from 0.9% to 1.6%, Mexico—from 0.7% to 2.1%, Argentina—from 0.6 to 1.2%, Chile—from 0.3% to 0.5%, but decreased in Venezuela—from 0.6% to 0.1% and Cuba—from 0.7% to 0.3%.

7.1 Distribution of S&T Papers

(a) By type of collaboration

As a result of collaboration between Indian and Latin American Scientists, 389 joint co-authored papers in S&T were published as per SCI database from 1996 to 2000.

Thus, on an average there were 78 co-authored publications per year. These collaborations have also depicted in increasing trend over these years, from 53 co-authored papers in 1996 to 100 in 2000 (Table 2).

Table 2. Year-wise break-up of papers between India and Latin America by type of collaboration

Year	Type of collaboration		
	Bilateral papers	Multilateral papers	Total papers
1996	15	38	53
1997	16	40	56
1998	22	61	83
1999	24	73	97
2000	39	61	100
Total	116	273	389

Of the 389 total co-authored papers, only 116 papers (29.82%) were bilateral in nature, i.e., those involved the participation of Indian and any one Latin American country.

The remaining 273 papers (70.28%) were multilateral in nature, i.e., involved the participation of more than two countries, one Indian and one Latin American and at least one other country (Table 3).

Table 3. Country-wise breakup of collaborative papers by nature of collaboration

Country	Nature of collaboration		
	Bilateral	Multilateral	Total papers
Brazil	50	179	229
Mexico	53	126	179
Argentina	1	95	96
Columbia	-	83	83
Chile	6	32	38
Venezuela	2	12	14
Peru	2	7	9
Cuba	2	4	6
Ecuador	-	23	23
Guatemala	-	5	5
Costa Rico	-	5	5
Honduras	-	1	1
Cote Ivory	-	1	1

In the 389 joint co-authored papers, India's collaboration with Latin American countries was as follows: India - Brazil (229 papers), India - Mexico (179 papers), India - Argentina (96 papers), India - Columbia (83 papers), India - Chile (38 papers), India - Ecuador (23 papers), India - Venezuela (14 papers), India - Peru (9 papers), India - Cuba (6 papers), India - Guatemala (5 papers), India - Costa Rica (5 papers), India - Honduras (1 paper) and India - Cote Ivory (1 paper) (Table 3). The total number of joint co-authored papers (Table 3) under these 13 categories is 689 instead of 389 co-authored papers. This is because of the fact that in many multilateral co-authored papers, India has collaboration with more than 2 Latin American countries simultaneously.

Except for Brazil and Mexico, a strong multilateral collaboration was found to exist between India and 12 other Latin American countries' scientists. Under India-Brazil and India-Mexico collaborations, the shares of bilateral co-authored papers were only 21.83% and 29.61% of the total co-authored papers (Table 3).

(b) Distribution by subject

The distribution of 389 co-authored papers under ten broad subjects was highly uneven. Physics had the largest share with 189 papers (48.58%), followed by Clinical Medicine (60 papers, 15.42%), and Earth & Space Sciences (49 papers, 12.59%). Six broad subjects each contributing less than 10 per cent to the total output were: Chemistry (29 papers, 7.45%), Biomedical Research (28 papers, 7.20%), Biology (13 papers, 3.34%), Engineering and Technology (8 papers, 2.06%), and Mathematics (3 papers, 0.77%) (Table 4).

Among these broad subjects, bilateral collaborations had larger share in three subjects, namely Engineering & Technology (87.5%), Chemistry (68.96%), and Mathematics (66.66%), while in other broad subjects, multilateral collaborations had major share: Clinical Medicine (96.66%), Earth & Space Science (73.47%), Biomedical Research (71.43%), Physics (69.84%), and Biology (69.23%) (Table 5).

India's collaboration with Brazil and Mexico in S&T in particular was more widespread and covered almost all broad disciplines, while its collaborative efforts with other Latin America countries were very

narrow and focused only in a few disciplines (Table 5).

Physics accounted for largest share of India's collaborative research with Ecuador (95.65%), followed by Columbia (91.57%), Argentina (82.29%), Mexico (64.25%), Brazil (63.32%), and Venezuela (57.14%). Clinical Medicine accounted for India's largest share in collaborative publications with Guatemala (60%), Cuba (50%), Peru (44.44%), Chile (42.10%), and Costa Rica (40%) and third largest with Brazil (10.04%), and Mexico (8.38%). Chemistry accounted for second largest share in India's collaborative research with Mexico (10.05%) and third largest share with Chile (10.52%). Biomedical Research accounted for second largest share in India's collaborative research with Guatemala (40%), Venezuela (35.71%), Peru (33.33%) and Columbia (6.02%) and fourth largest share with Brazil (6.11%). Biology accounted for second largest priority area under India's collaborative research with Argentina (4.16%).

7.2 Bilateral S&T Collaborations

India's bilateral collaborations with Latin American countries resulted in 116 co-authored papers from 1996 to 2000. The

Table 4. Subject-wise distribution of collaborative papers (along with impact factor) by type of collaboration

Subject	Bilateral	Multilateral	Total Papers
Physics	57(1.91)	132(3.95)	189(3.33)
Chemistry	20(1.29)	9(1.03)	29(1.21)
Earth & Space Sciences	13(2.04)	36(2.42)	49(2.31)
Engineering & Technology	7(0.48)	1(0.18)	8(0.44)
Biomedical Reserach	8(1.45)	20(4.20)	28(3.41)
Clinical Medicine	2(3.41)	58(3.94))	60(3.92)
Biology	4(0.56)	9(0.99)	13(10.86)
Mathematics	2(0.82)	1(1.33)	3(0.99)
Social Sciences	1(0.51)	-	1
Multidisiplinary Science	2(0.51)	5(12.36)	7
Unassigned	-	2	4
Total	116(1.62)	273(3.68)	391

Table 5. India's coauthored papers with other Latin American Countries in different S&T disciplines

Subject	Total Papers	Brazil	Mexico	Argentina	Chile	Venezuela	Peru	Cuba	Colombia	Ecuador
Physics	189	145	115	79	2	8		1	76	22
Clinical Medicine	60	23	15	3	16	-	4	3	5	1
Earth & Space Sciences	49	24	16	6	13	-	-	1	2	
Chemistry	29	7	18	-	4	-	-	-		
Biomedical Research	28	14	4	2		5	3	1		
Biology	13	5	5	4	-	1	2			
Engineering & Technology	8	6	1	-	-					
Multidisciplinary Science	7	3	2	2	1					
Mathematics	3	-	1	-	2					
Social Sciences	1	-	1	-	-					
Unassigned	2	2	1	-	-					
Total		229	179	96	38	14	9	6	83	23

maximum papers (53) were with Mexico, followed closely by Brazil (50 papers). The number of papers with some other countries was quite less, viz., Chile (6 papers), Cuba, Venezuela and Peru (2 papers each) and Argentina (1 paper) (Table 6).

7.2.1 Classification into Subjects

These 116 bilateral co-authored papers could be classified in 10 broad subject fields and 31 sub-fields. Its distribution across broad subject fields is skewed for 'Physics', 'Chemistry', and 'Earth & Space Sciences', accounting for 49.14%, 17.24% and 11.20% of the total co-authored papers, respectively. The subjects which received comparatively less attention were: Biomedical Research (6.89%) and Engineering & Technology (6.034%).

The classification of these papers into sub-fields revealed the emphasis on the following areas under each broad subject: *Physics*—General Physics (29 papers), Nuclear Physics (8 papers), Solid State Physics (7 papers) and Applied Physics

(5 papers); *Chemistry*—Physical Chemistry (8 papers) and Organic Chemistry (5 papers); *Earth & Space Sciences*—Astronomy & Astrophysics (7 papers) and Earth & Planetary Science (5 papers); and *Biomedical Research*—Biochemistry & Molecular Biology (3 papers).

7.2.2 Impact of Bilateral Co-authored Papers

The impact of the bilateral co-authored papers on different disciplines was analysed through the values of impact factor (IF) of the journals in which these papers were published. Considering the impact of all co-authored papers, the average impact factor per paper was calculated as 1.62.

The average impact factor per paper for various disciplines in terms of ranking was 3.41 for Clinical Medicine, 2.04 for Earth & Space Sciences, 1.91 for Physics, 1.45 for Biomedical Research, 1.29 for Chemistry, 0.82 for Mathematics, 0.56 for Biology, 0.51 for Social Sciences and Multidisciplinary Sciences.

Table 6. Distribution of bilateral collaborative papers (along with IF per paper) by subjects

Subject	Latin America	Brazil	Mexico	Chile	Cuba	Venezuela	Peru	Argentina
Physics	57(1.91)	33(2.41)	20(0.94)	1(1.27)		2(2.10)		1(4.21)
Chemistry	20(1.29)	3(0.85)	13(0.88)	4(2.95)				
Engineering & Technology	7(0.48)	5(0.47)	1(0.42)		1(0.58)			
Earth & Space Sciences	13(2.04)	3(1.34)	10(2.25)					
Biomedical Research	8(1.45)	4(0.80)	3(2.22)		1(1.74)			
Clinical Medicine	2(3.41)	1(4.20)	1(2.61)					
Biology	4(0.56)		2(0.56)				2(0.55)	
Mathematics	2(0.82)		1(0.63)	1(1.02)				
Social Sciences	1(0.51)		1(0.51)					
Multidisciplinary Science	2(0.51)	1(0.51)	1(0.51)					
Unassigned	–							
Total	116(1.62)	50(11.93)	53(1.23)	6(2.51)	2(1.16)	2(2.10)	2(0.55)	1(4.21)

7.2.3 Analysis of Priorities in Bilateral Collaboration (Country-wise)

Physics contributed the largest share of India's collaborative papers with Venezuela (100%), Brazil (66%) and Mexico (37.74%). The share of Chemistry in India's co-authored papers was significant with Chile (66.66%) and second important with Mexico (24.53%). Earth & Space Sciences made third significant contribution to India's collaboration with Mexico (24.53%). In Biomedical Research, India's comparatively more significant collaboration was with Brazil (8%) and Mexico (5.66%). Biology made important contribution in India's collaboration with Peru (100%) and Mexico (3.77%).

(a) India – Mexico Collaboration

The 53 bilateral co-authored papers resulting from India-Mexico collaborative research were distributed across 10 broad subjects. The distribution was highly skewed in favour of Physics (37.74%), Chemistry (24.53%) and Earth & Space Sciences

(18.87%). The impact of bilateral co-authored papers varied from 0.51 to 3.41 across broad subjects and the average IF per paper was 1.62. The three broad subject areas, which received impact greater than the average IF were: Clinical Medicine (3.41), Earth & Space Sciences (2.04) and Physics (1.91). A total of 27 Indian and 24 Mexico institutions were involved in this bilateral research.

The major collaborative institutions from Mexico were:

- (i) *Universidad Nacional Autonoma de Mexico, Instituto de Quimica, Coyoacan, Mexico* (13 papers)
- (ii) *Universidad Autonoma Metropolitana-Azcapotzalco Campus, Mexico City* (7 papers)
- (iii) *Instituto Nacional Astrofisica, Optica y Electronica, Puebla* (5 papers), and
- (iv) *Universidad Autonoma Metropolitana-Iztapalapa, Mexico city* (4 papers).

The major collaborating institutions from India were:

- (i) Sri Aurobindo International Centre of Education, Pondicherry (7 papers),
- (ii) Indian Institute of Technology, New Delhi (6 papers),
- (iii) University of Madras (5 papers),
- (iv) Tata Institute of Fundamental Research (TIFR), Mumbai (4 papers), and
- (v) Indian Institute of Astrophysics, Bangalore (3 papers).

Looking at the strength of collaboration, it has been observed that the following pairs of institutions co-authored more than one bilateral paper:

- (i) Sri Aurobindo International Center of Education, Pondicherry and *Universidad Autonoma Metropolitana- Azcapotzalco* Campus, Mexico City (5 papers),
- (ii) University of Madras and *Universidad Nacional Autonoma de Mexico, Instituto de Quimica*, Coyoacan, Mexico (5 papers),
- (iii) Indian Institute of Technology, New Delhi and *Universidad Nacional Autonoma de Mexico, Instituto de Quimica*, Coyoacan, Mexico (4 papers),
- (iv) Indian Institute of Astrophysics, Bangalore and *Institutueo Nacional Astrofisica, Optica y Electronica*, Puebla (2 papers),
- (v) National Geophysics Research Institute, Hyderabad and *Universidad Nacional Autonoma de Mexico, Institute of Geofis* (2 papers), and
- (vi) Bharathidasan University and *Universidad Nacional Autonoma de Mexico, Instituto de Quimica*, Coyoacan, Mexico (2 papers).

(b) India – Brazil Collaboration

The 50 bilateral co-authored papers resulting from India-Brazil collaborative research were distributed across 7 broad subject fields, with focus on Physics (33 papers, 66%), Engineering & Technology (5 papers, 10%), Biomedical Research (4 papers, 8%), and Chemistry & Earth & Space Sciences (3 papers each, 6% each). The impact of bilateral co-authored papers varied from 0.51 to 4.20 across broad subjects and the average IF per paper was 1.93. The two fields registering the impact above the

average IF were: Clinical Medicine (4.20) and Physics (2.41).

About 30 Indian and 19 Brazilian institutions are involved in bilateral collaborative research. The major collaborative research institutions from Brazil were:

- (i) *Universidad Federal de Estadual -Paulista, Institute Fis-Teor*, Sao Paulo (12 papers),
- (ii) *Universidad Federal de Janeiro, Inst-Fis*, Rio de Janeiro (4 papers),
- (iii) *Universidad Federal de Pernambuco, Dept-Fis*, Recife (4 papers),
- (iv) *Universidad Federal de Fluminense, Inst-Fis*, Niteroi (4 papers),
- (v) *Universidad Sao Paulo, Inst-Fis*, Sao Paulo (4 papers), and
- (vi) *Universidad Federal de Parana*, Parana (3 papers).

The important collaborative research institution from India were:

- (i) S N Bose National Center for Basic Sciences, Calcutta (4 papers),
- (ii) National Physical Laboratory, New Delhi (4 papers),
- (iii) Visva Bharati, Santiniketan (5 papers), and
- (iv) Regional Research Laboratory, Trivandrum (3 papers).

Looking at the strength of collaboration, it has been observed that the following pairs of institutions co-authored more than one bilateral paper:

- (i) Indian Association for Cultivation of Science, Calcutta and *Universidad Federal de Estadual - Paulista, Institute Fis-Teor*, Sao Paulo (5 papers),
- (ii) S N Bose National Center for Basic Sciences, Calcutta and *Universidad Federal de Janeiro, Inst-Fis*, Rio de Janeiro (3 papers), and
- (iii) National Physical Laboratory, New Delhi and *Universidad Federal de Pernambuco, Recife* (2 papers).

7.2.4 Institutional Participation in Bilateral Collaborative Research

In all 52 Indian organizations (25 are universities, 23 research institutes, 2 colleges,

1 industrial research and one other) are involved in bilateral collaborative research with those of Latin America. Among these Indian organisations 29, 10 and 4 have contributed one, two and three collaborative papers each.

A list of Indian organisations collaborating in more than 3 papers with Latin America were:

- (i) Tata Institute of Fundamental Research, Mumbai (7 papers)
- (ii) Sri Aurbindo International Center of Education, Pondicherry (7 papers)
- (iii) Indian Association for Cultivation of Science, Calcutta (6 papers)
- (iv) Indian Institute of Technology, New Delhi (6 papers)
- (v) Indian Institute of Technology, New Delhi (6 papers)
- (vi) Visva Bharati University, Shantineketan (6 papers)
- (vii) University of Hyderabad (5 papers)
- (viii) University of Madras (5 papers) and

(ix) S N Bose National Center for Basic Sciences, Calcutta (5 papers).

7.3 Multilateral Collaborations of Indian with Latin American Countries in S&T

Among the 273 multilateral co-authored papers, 164 involved the participation of India with at least one Latin American country, and other countries outside the Latin America. Six papers, 50 papers and 22 papers had the participation of India along with three, four and five Latin American countries simultaneously.

Among multilateral collaborative papers, the largest number (179) was through India-Brazil collaboration, followed by India - Mexico (126 papers), India - Argentina (95 papers), India - Columbia (83 papers), India - Chile (32 papers), India - Ecuador (23 papers), India - Venezuela, (12 papers), India-Peru (7 papers), India - Costa Rica and India-Guatemala (5 papers each), India - Cuba (4 papers), India - Honduras and India - Cote Ivory (1 paper each) (Table 7).

Table 7. Distribution of multilateral collaborative papers (along with IF per paper) by subjects

Subject	Total Papers	Brazil	Mexico	Argentina	Chile	Venezuela	Peru	Cuba
Physics	132(3.95)	112(4.09)	95(4.58)	78(5.22)	1(3.06)	6(3.31)		1(2.27)
Chemistry	9 (1.03)	4(0.85)	5(1.17)					
Earth & Space Sciences	36(2.42)	21(2.56)	6(2.91)	6(2.13)	13(2.21)			
Biology	9(0.99)	5(1.29)	3(0.66)	4(1.10)		1(3.55)		
Biomedical Reserach	20(4.20)	10(5.99)	1(2.54)	2(5.23)		5(4.55)	3(2.16)	
Clinical Medicine	58(3.94)	22(3.48)	4(2.99)	3(2.77)	16(3.67)		4(7.19)	3(2.16)
Engineering & Technology	1(0.18)	1(0.18)	-					
Mathematics	1(1.33)		-		1(1.33)			
Multidisiplinary Science	5(12.36)	2(5.68)	2(5.84)	2(5.92)	1(23.60)			
Unassigned	2(0.96)	2(0.96)	1(0.58)					
Total	273(3.68)	179(3.76)	26(4.22)	95(4.79)	32(3.61)	12(3.85)	7(5.18)	4(2.19)

7.3.1 Priority of Subject Areas and Their Impact Under Multilateral Collaboration

The largest number of joint co-authored papers was published in Physics (132 papers) followed by Clinical Medicine (58 papers) Earth & Space Sciences (36 papers) and Biomedical Research (20 papers). The 132 multilateral co-authored papers in Physics were spread in 6 sub-disciplines, viz. general physics (61 papers), nuclear & particle physics (48 papers), applied physics (14 papers), chemical physics (4 papers), solid-state physics (3 papers), and optics (2 papers). The 58 papers in Clinical Medicine were in 19 sub-disciplines, with focus on general & internal medicine (15 papers), environment & occupational health (6 papers), cardiovascular system (5 papers), fertility (5 papers), immunology (4 papers) and neurology & neurosurgery (4 papers). The 36 papers in Earth & Space Sciences were in three sub-disciplines, with focus on astronomy & planetary sciences (12 papers). The 20 papers in Biomedical Research were in eight sub-disciplines, with focus on genetics & heredity (5 papers), microbiology (4 papers), biomedical engineering (3 papers) and virology (3 papers).

The average value of IF per paper in multilateral papers was 3.68, much higher than that of bilateral collaborative papers. The papers (7) through India - Peru collaboration have received the highest value of IF (5.18), followed by India - Columbia (5.08), India-Ecuador (4.95), India - Argentina (4.79), India- Mexico (4.22), India - Venezuela (3.85), India - Brazil (3.76), India - Chile (3.61), India-Honduras (3.26), India - Guatemala (2.68), India - Cuba (2.19), collaborations.

7.3.2 Number of Countries Participating per Paper in Multilateral Collaborations

A total of 87 countries participated in multilateral collaborated papers, among which 74 countries were from outside Latin America. These countries participated in various combinations, ranging from 3 to 28. Around 48 per cent of the multilateral collaborative

papers emanated from the team efforts of three to five countries. The participating teams comprising 11 to 28 countries accounted for only 15 per cent of the total multilateral papers. Among 74 countries participating outside Latin America, the largest participation was from the USA (185 papers), followed by France (112 papers), Russia (82 papers), South Korea (70 papers), the UK (69 papers), Poland (64 papers), China (50 papers), Italy (34 papers), Germany (38 papers), and Australia (31 papers).

7.3.3 Institutional Participation per Paper in Multilateral Papers

The number of institutions collaborating per paper from various participating countries in multilateral papers ranged from 3 to 50. The participation of three to five institutions was in 38 per cent of the total papers. On the other hand, participation of 11 to 43 institutions accounted for 20.51 per cent of all papers, while in 53 papers, the number of participating institutions varied from 44 to 50.

CONCLUSIONS

A study on India's S&T collaboration with Latin America countries has been presented through the analysis of joint co-authored research papers published during 1996-2000 in journals covered by SCI. As an outcome of these collaborations, a total of 389 joint co-authored papers were published in which 116 papers were under bilateral collaborations and 273 under multilateral collaborations. India's most significant collaborative partners along with their co-authored output were Brazil (229 papers), Mexico (179 papers), Argentina (96 papers), Columbia (83 papers), Chile (38 papers), Ecuador (23 papers), Venezuela (14 papers), and Peru (9 papers). Except for Brazil and Mexico a very strong multilateral collaboration exists between India and 12 other Latin American countries. The most preferred and dominant areas of collaboration have been found to be Physics, Clinical Medicine and Earth & Space Sciences contributing together more 75 percent of the India's collaborative output with Latin America countries. Clinical

Medicine and Earth & Space Sciences, in particular has registered a high fact, both under bilateral and multilateral collaborations. Besides Latin American countries, 74 other countries also participated in multilateral collaborative research output. Among these countries the largest participation was from USA (185 papers), and France (112 papers).

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