S&T collaboration of India with other South Asian countries

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Science and technology (S&T) is being practised today in a collaborative manner with participation of scientists from different disciplines, institutions and countries. To combat the problems of pollution, environment, energy, biodiversity, health and nutrition, many countries in the world, particularly the developing countries, need cooperation and support from other developed countries. Thus, collaboration in S&T is fast emerging as the keyword in the scientific world. India had recognized the importance of international scientific collaboration quite early and considers it an important instrument for the development of S&T in India. As a result, India has signed a number of collaboration agreements on S&T with many countries, including South Asian countries. In this article, a study on the outputs of S&T collaborations is presented through the analysis of co-authored research papers published during the period 1992–99 in the journals covered by the Science Citation Index. The study analyses these collaborations from various angles, viz. nature, S&T areas, institutions involved and their impact on individual fields. It has been observed that of the four South Asian countries – Bangladesh, Pakistan, Sri Lanka and Nepal – India had stronger collaborative linkages with Bangladesh, covering the major broad areas in S&T, and the co-authored papers resulting out of these collaborations had high values of impact factor. Collaboration with other South Asian countries had been quite narrow and restricted to few subject areas. Need for further cooperation is highlighted in newly emerging areas of S&T.

SCIENCE and technology (S&T) today has acquired an international character. It is not possible for many countries in the world, particularly the developing countries, to conduct scientific research at individual levels. They need the cooperation of other countries, which have the necessary knowledge-base and infrastructure along with the will to collaborate. In dealing with problems such as environment degradation, loss of biodiversity, pollution control, health and nutrition, developing countries face limitations like weak national S&T infrastructure, lack of trained S&T personnel, inadequate funding, weak and inadequate communication, internal upheavals (political, economic, and cultural), and linguistic problems. To cope with such problems research collaborations are, in fact, emerging as an important catalysis for accelerating research in these areas. In areas like traditional medicine, these collaborations are assuming greater significance because now even the developed countries want to have linkages with the developing countries for the flow of knowledge. Thus, science is being practised today in a collaborative manner with participation of two or more countries. There are many factors which directly or indirectly affect the collaboration among nations – economic and educational exchanges with the political relationship being the most important.

India has taken several initiatives to strengthen bilateral economic cooperation with some of the South Asian countries[1]. India's foreign direct investments (FDIs) in fellow South Asian countries are small at present (except in Nepal), but are on the rise in some of these countries. India's investment as a percentage of total approved FDI flow has particularly increased in Bangladesh from 3.93 to 8.04% and in Nepal from 17.59 to 61.44%, but decreased in Pakistan from 0.008 to 0.002% and in Sri Lanka from 1.07 to 0.91% during 1990–99 (ref. 1). These investments are confined to mainly joint ventures in Sri Lanka, Nepal and Bangladesh[2]. In Nepal, Indian companies govern 72 out of 214 foreign ventures, accounting for 53% of the total capital of foreign ventures. Out of these 72 ventures, 14 are engaged in textiles and ready-made garment exports. Sri Lanka is already a host to about 90 Indian ventures with a total investment of US $109 million, essentially in light engineering goods, automobiles, hotels, etc. India's recent joint ventures in Sri Lanka include Gujarat Ambuja's $50 million cement

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plant, Apollo hospital's 27% equity stake in a $25 million hospital, and NIIT initiatives for software development. The recent times have also witnessed an intensification of industrial and investment linkages between India and Bangladesh. One successful example of this cooperation is the production of a joint venture on fine ceramics in Bangladesh (as a result of a collaboration between Abheesht Exports of New Delhi and Beximco, the largest industrial conglomerate in Bangladesh)[1]. This Indo-Bangladesh joint venture aims at exploiting the location advantages of Bangladesh as a production base.

For successful academic and educational cooperation, it is necessary to establish partnership with institutions in both developed and developing countries with a view to facilitate faculty and student exchanges and undertaking joint research and development projects. Such exchanges later become the foundation for future research cooperation. A large number of students, particularly from Nepal, Bangladesh and Sri Lanka, come to India for higher studies. For example, during 1998–99, out of 2197 students that went abroad for higher studies from Nepal, 574 came to India. These figures for Bangladesh were 461 out of 5779 students and 368 out of 5118 for Sri Lanka[3].

India participates in several bilateral and multilateral educational programmes related to the exchange of scholars through a number of scholarship and fellowship schemes. For extending friendly relations, the Government of India offers about 1000 scholarships every year to the nationals of 70 African, Asian and other developing countries for undergraduate and postgraduate studies at universities and educational institutions in India. Also as a member of the Commonwealth, India participates in a number of exchange programmes floated by this group. Under the Technical Cooperation Scheme of the Colombo Plan, the Government of India offers assistance for placement of scholars coming from different countries of the sub-region. Also more than 100 scholarships are offered every year to the nationals of Bangladesh and Nepal for engineering courses in India. In addition, India offers technical training to foreign technical personnel and scientists from developing countries in different fields of S&T under various other exchange programmes.

Existing modes of S&T collaboration

India's collaboration with other South Asian countries is being undertaken through bilateral, regional and multilateral agreements. Among bilateral collaborations, India has taken some initiatives and has signed bilateral agreements in S&T[5] with Bangladesh (1982), Pakistan (1983), Sri Lanka (1975) and Nepal; yet a majority of actual collaborations are undertaken under the umbrella of regional and international cooperation, through various agencies of the United Nations such as UNESCO, ILO, WHO, UNEP, FAO, UNIDO, IAEA and the World Bank. Bilateral collaborations have been mostly in the form of training of S&T personnel, exchange of scientists, and conduct of joint research and development projects.

The idea of regional cooperation was also conceived under the South Asian Association for Regional Cooperation (SAARC). India played a major role in promoting collaboration under SAARC. At present there are twelve areas of cooperation under SAARC, which include agriculture, communication, environment, health and population activities, and S&T. The cooperation is carried out through various technical committees (TCs), such as the ones on agricultural sector, communication, environment and meteorology, rural development, S&T, tourism, etc. The SAARC Technical Committee on S&T promotes cooperation among member countries through workshops, expert group meetings, circulation of state-of-the-art reports on different S&T sectors, training of scientists, and initiating joint research and development projects in the areas of energy, food technology, natural resource surveys and remote sensing, forestry development and erosion control, mining and ore beneficiation, microelectronics, marine sciences, instrumentation, solar technology, genetic engineering, environment and informatics. There are also four SAARC regional centers, viz. Agricultural Information (Bangladesh), Tuberculosis (Nepal), SAARC Documentation Centre (India), and Meteorology Research (Bangladesh), which stimulate cooperation among these countries[6].

The regional cooperation is also fostered through different agencies and their programmes, such as South Asian Cooperative Environment Programme (SACEP); Commonwealth Science Council Programmes; Association for Science Cooperation in Asia; Economic and Social Commission for Asia and Pacific Programme; Committee on Science and Technology in Developing Countries (COSTED); NAM S&T Centre; Regional Cooperation Agreement for Research, Nuclear Science and Technology (RCAR) sponsored by International Atomic Energy, Vienna, Austria, The Third World Academy of Sciences; International Center of Theoretical Physics, Trieste, and the International Development Research Centre, Ottawa. These agencies and programmes are playing significant roles in exchange of information, training of technical personnel and scientists and conducting of joint research and development projects among developing countries, including those pertaining to S&T.

India's collaboration with fellow South Asian countries has resulted in different kinds of outputs, which include joint research publications, technology development and transfer, and development of products and processes. The joint research publication is an important indicator of the strength of research collaboration and its impact on different fields. This particular information on collaborated output is comparatively well documented in

printed and computerized databases. However, there are hardly any sources through which other outputs of these collaborations could be easily documented and studied.

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 Nagpaul[7] was focused on the analysis of the transnational linkages of Indian science in eleven scientific fields with 35 most significant partner countries during 1990–94. The study by Basu *et al*[8]. presented the international collaboration in Indian science from *SCI* data for 1990 and 1994. Both the studies give an overview of India's collaboration in S&T as reflected in its output in *SCI*, but fail to analyse India's collaboration profile and linkages at bilateral and multilateral levels with individual countries and regions.

Objectives

The aim of this article is to study research collaborations of India with four fellow South Asian countries, with main objectives being: (i) study of the nature of Indian collaboration with other South Asian countries in S&T, as reflected in co-authored research papers, (ii) identification of the subject areas of collaboration, (iii) evaluation of impact of such collaborative research, and (iv) highlighting the major Indian and South Asian institutions involved in these collaborative research activities and programs.

Databases and methodology

The data for the study were culled from the CD-ROM version of the international database of *SCI*, for a period of eight years from 1992 to 1999. This database covers around 5000 significant journals of the world in all major fields of S&T. However, it covers only a few domestic journals published from the South Asian countries. The journals covered by *SCI* represent the mainstream S&T. As a result, this study is restricted to the co-authored articles generated from India's collaboration with South Asian countries and published mainly in quality international journals covered by *SCI*. The articles were classified under ten major disciplines and 61 sub-disciplines, according to the scheme suggested by Computer Horizon Inc, USA. In this scheme, each article is classified into a main discipline and a sub-discipline using the subject title of the journal in which it is published.

Some of the terminologies used in this article are briefly described below: (i) Collaborating countries – the name of the countries collaborating in a paper was judged from the 'affiliation' of the authors provided in the publication, (ii) Nature of collaboration – (a) bilateral: if there were only two countries – one India and one other South Asian country – the collaboration was termed as 'bilateral', and (b) multilateral – if there were more than two countries – one India and at least one South Asian country – the collaboration was termed as 'multilateral', (iii) Collaboration linkage – this represents the linkages between the institutions of one country with those of the other collaborating countries. For example, if there are three authors in a co-authored paper, one belonging to an Indian institution and the other two belonging to two different institutions from Bangladesh, we say that one Indian institution has two collaborative linkages with Bangladeshi institutions, (iv) Impact factor (IF) – this term, coined by the Institute of Scientific Information (ISI), Philadelphia, USA in the year 1970, 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 covered in the *SCI*. This is calculated annually for each journal covered in *SCI* and is listed in the *Journals Citation Report* brought out by ISI, annually. In spite of its several limitations, IF remains the most widely used tool for objective evaluation of the impact of research publications (as seen through their publication in journals) of different fields, institutions and countries.

S&T research output of South Asian countries

Before studying the status of India's collaboration with other South Asian countries, let us look at the S&T research output of individual South Asian countries, as reflected in the *SCI* database for the period 1992–99. This is shown in Table 1.

It is clear from Table 1 that there is a wide gap between the research output of India and other South Asian countries, namely Pakistan, Bangladesh, Sri Lanka and Nepal. The average number of publications per year from these countries during 1992–99 was: 11429 for India, 401 for Pakistan, 221 for Bangladesh, 118 for Sri Lanka and 65 for Nepal. There is no consistency in the growth rate of publications from these South Asian countries; the number of publications, however, remained within a particular limit only and there were no marked jumps or falls in these publication numbers.

India's collaboration in S&T with other South Asian countries

India's collaboration with Bangladesh, Pakistan, Nepal and Sri Lanka during 1992–99 had resulted in 178 joint co-authored papers in different fields of S&T. This means that on an average, 22 joint co-authored papers were published per year. These papers have appeared in different formats: 161 as research articles and others as review articles, letters to the editor and notes, meeting abstracts, editorial material and discussion.

Table 1. Year-wise S&T research output of South Asian countries for the period 1992–99

Country	Year-wise number of publications as per *SCI* database							
	1992	1993	1994	1995	1996	1997	1998	1999
India	11160	10977	11319	11084	11177	11067	12128	12521
Pakistan	355	443	413	444	367	344	424	424
Bangladesh	195	200	187	240	228	227	232	263
Sri Lanka	118	108	122	115	109	102	122	147
Nepal	49	49	49	76	50	72	77	96

Table 2. India's co-authored papers with other South Asian countries in different S&T disciplines

S&T disciplines	Number of papers co-authored by India with other South Asian countries				
	Bangladesh	Pakistan	Nepal	Sri Lanka	Total
Physics	32	2	3	–	37
Earth and space sciences	4	–	2	4	10
Clinical medicine	29	7	10	6	51
Biomedical research	11	2	3	–	15
Biology	7	8	10	3	25
Engineering and technology	21	–	1		22
Chemistry	9	4	–	–	13
Mathematics	1	–	–	–	1
Health sciences	1	–	–	–	1
Multidisciplinary sciences	3				3
Total	118	23	29	13	178

In the 178 joint co-authored papers, India's collaboration with fellow South Asian countries was as follows: India–Bangladesh: 118 papers, India–Nepal: 29 papers; India–Pakistan: 23 papers, and India–Sri Lanka: 13 papers. The total number of joint co-authored papers under these four categories, is 183 instead of 178. This is because of the fact that in 5 co-authored papers, India has collaborated with two South Asian countries simultaneously. Among these 178 joint co-authored publications, 95 were under bilateral collaborations and 83 under multilateral collaborations.

The distribution of these 178 co-authored papers under ten major disciplines was highly uneven. Clinical medicine had the largest share with 51 papers (28.65%), followed by physics 37 (20.78%) papers, biology 25 (14.04%) papers, and engineering and technology 22 (12.36%) papers. Six disciplines contributing less than 10% publications were: biomedical research 15 (8.43%) papers, chemistry 13 (7.30%) papers, earth and space sciences 10 (5.62%) papers, multidisciplinary sciences 3 (1.68%) papers, health sciences 1 (0.56%) paper and mathematics 1 (0.56%) paper.

India's collaboration with Bangladesh in S&T in particular was much more widespread and covered almost all major disciplines, while its collaborative efforts with Pakistan, Nepal and Sri Lanka was narrow and focused in only a few disciplines (Table 2).

The impact of these co-authored papers was analysed through the IF of journals in which these papers were published. Considering the impact of all co-authored papers, the mean average impact factor per paper was observed to be 1.997. It was 1.813 for bilateral papers and 2.22 for multilateral papers. The average value of IF per paper under various disciplines, in terms of ranking was: 10.127 for multidisciplinary sciences (3 papers), 3.828 for clinical medicine (51 papers), 3.596 for health sciences (1 paper), 1.587 for biomedical research (15 papers), 1.278 for biology (25 papers), and 1.159 for physics (37 papers). In all other disciplines, the average IF value was below one: 0.852 for chemistry (13 papers), 0.659 for earth and space sciences (10 papers), 0.443 for engineering and technology (22 papers), and 0.338 for mathematics (1 paper).

The maximum number of these co-authored papers was published in the discipline of clinical medicine, which also had the highest impact (in terms of IF). It was probably because of the increased interest in health-related problems and application of research outputs in dealing with environment health hazards.

There were 128 journals in which these 178 collaborative papers were published. Among these journals, 94 journals have published only 1 paper, 24 journals 2 papers, 6 journals 3 papers, 3 journals 4 papers and one journal 6 papers. A list of journals in which three or more collaborated papers were published is given in Table 3. Among these, four were Indian: *Indian Journal of Chemistry, Section B* (3 papers), *Current Science* (2 papers), *Indian Journal of Chemistry, Section A* (2 papers), and *Pramana* (1 paper).

Table 3. Some represented journals covered by *SCI* where collaborative research in S&T was published

Journal	No. of papers contributed
Lancet	6
Journal of Physics – Condensed Matter	4
Thin Solid Films	4
WHO Technical Report Series	4
Acta Paediatrica	3
Bulletin of the World Health Organization	3
Euphytica	3
Indian Journal of Chemistry, Section B	3
Physica Scripta	3
Warne und Staffuberttragung-Thermo Fluid	3

A total of 154 institutions from South Asian countries was involved in the collaborative research during the period under study. Among these, 61 were from India, 32 from Bangladesh, 27 from Pakistan, 21 from Nepal and 7 from Sri Lanka. The Indian institutions along with their individual collaborated publications and collaborative linkages reflected in them with institutions in fellow South Asian countries are given in Table 4.

Bilateral S&T collaborations of India with other South Asian countries

India's bilateral collaborations with fellow South Asian countries had resulted in 95 co-authored papers. The maximum (71) papers were published through the collaboration of India with Bangladesh, followed by its collaboration with Nepal (14 papers), Pakistan (6 papers), and Sri Lanka (4 papers). The 95 bilateral co-authored papers were in nine major disciplines (Table 5).

Major priority subject areas and their impact under bilateral collaboration

The largest number of papers was published in the area of engineering and technology (22 papers) and the least in mathematics (1 paper). The subject-wise and country-wise break-up of these papers is given in Table 5 along with their average IF values. A further break-up of these collaborative papers under various sub-fields is described in more detail as follows.

The 22 papers in engineering and technology were spread over eight sub-disciplines: metals and metallurgy (6 papers), mechanical engineering (4 papers), electrical and electronic engineering (3 papers), computers (3 papers), and civil engineering (3 papers). There was one collaborative paper each in materials science, operations research and miscellaneous engineering and technology. Most of these papers had resulted from India–Bangladesh collaboration and there was only one paper in civil engineering under India–Nepal collaboration. The distribution of 21 bilateral papers in physics was: general physics (11 papers), applied physics (6 papers), solid-state physics (2 papers), fluid and plasma physics (1 paper), and nuclear and particle physics (1 paper). Most of these papers had resulted from India-Bangladesh collaboration, only three papers in general physics and one paper in applied physics were from India-Nepal and India-Pakistan collaborations.

The 17 bilateral papers in clinical medicine were spread in ten sub-disciplines: paediatrics (4 papers), general and internal medicine (3 papers), environment and occupational health (2 papers), endocrinology (2 papers), gastroenterology (1 paper), immunology (1 paper), pathology (1 paper), veterinary medicine (1 paper), tropical medicine (1 paper) and pharmacology (1 paper). Most of these papers had resulted from India–Bangladesh collaboration, except two (1 each in veterinary medicine and pharmacology), which were from India–Nepal collaboration; one paper each in tropical medicine and paediatrics has come out from India–Sri Lanka and India–Pakistan collaboration.

The 11 papers in chemistry were distributed in four sub-disciplines: organic chemistry (4 papers), physical chemistry (3 papers), inorganic and nuclear chemistry (3 papers), and analytical chemistry (1 paper). Most of these papers had resulted from India–Bangladesh collaboration, except two in organic chemistry, which were from India–Pakistan collaboration. The ten papers in biology were distributed in 4 sub-fields: agricultural and food science (6 papers), botany (2 papers) and 1 paper each in entomology and general biology. India–Nepal and India–Pakistan collaboration are concentrating on agricultural and food science with three and two papers. The six papers in biomedical research were distributed in five sub-disciplines: microbiology (2 papers) and one paper each in nutrition and dietetics, parasitology, physiology and miscellaneous biomedical research. The four papers in earth and space sciences are in two sub-fields: earth and planetary science (2 papers) and environment science (2 papers).

The average IF per paper based on bilateral co-authored papers was 1.813. The highest average value of IF was 2.153 under India–Bangladesh collaboration, followed by 0.845 under India–Pakistan collaboration, 0.832 under India–Nepal collaboration, and 0.663 under India–Sri Lanka collaboration. It was observed that India–Bangladesh bilateral, co-authored papers had the highest average values of IF in almost all disciplines, except in chemistry. The differences in the average values of IF were large in two disciplines, viz. clinical medicine and biology. The India–Nepal bilateral papers had comparable IF per paper in physics, and India–Pakistan bilateral papers had higher IF in chemistry over India–Bangladesh bilateral papers.

Table 4. Rank list of Indian institutions along with their contributions and collaborative linkages with institutions in South Asian countries

Indian institutions	No. of co-authored papers	Total no. of collaborative linkages	No. of collaborative linkages of individual Indian institutions with institutions of individual South Asian countries			
			Bangladesh	Nepal	Pakistan	Sri Lanka
Indian Institute of Technology (IIT), Kharagpur	15	15	15			
Banaras Hindu University (BHU), Varanasi	10	12	10	1	1	
National Institute of Cholera and Enteric Diseases (NICED), Kolkata	10	10	10			
Society of Applied Sciences (SAS), Kolkata	8	8	8			
Christian Medical College and Hospital, Vellore	7	7	5		1	1
IIT, New Delhi	6	6	1	3		2
Regional Research Laboratory (RRL), Bhubaneswar	6	6	6			
University of Calcutta, Kolkata	5	7	3	4		
S. N. Bose National Centre for Basic Research, Kolkata	5	8	8			
Jadavpur University, Kolkata	5	6	6			
Aligarh Muslim University, Aligarh	5	5	4	1		
Indian Agricultural Research Institute, New Delhi	4	8	2	5	1	
All India Institute of Medical Sciences, New Delhi	4	6	5			1
University of Roorkee, Roorkee	4	4	2	1		1
ICRISAT, Patancheru	4	4	2		1	1

Table 5. Major areas of bilateral collaboration with output of collaborative papers and the corresponding average IF

	Total papers along with average value of IF	Number of papers with the values of average impact factor (in parenthesis) in different subjects								
		Engineering and technology	Physics	Clinical medicine	Chemistry	Biology	Biomedical research	Earth and space sciences	Multi-disciplinary sciences	Mathe-matics
India–South Asia	95 (1.813)	22 (0.443)	21 (1.167)	17 (4.135)	11 (0.804)	10 (1.859)	6 (1.110)	4 (0.583)	3 (10.127)	1 (0.338)
India–Bangladesh	71 (2.15)	21 (0.464)	17 (1.198)	13 (4.994)	9 (0.661)	2 (7.222)	3 (1.512)	2 (0.710)	3 (10.127)	1 (0.338)
India–Nepal	14 (0.832)	1 (0.00)	3 (1.196)	2 (1.479)		4 (0.648)	3 (0.708)	1 (0.392)		
India–Pakistan	6 (0.845)		1 (0.530)	1 (1.462)	2 (1.45)	2 (0.09)	–	–	–	–
India–Sri Lanka	4 (0.663)	–	–	1 (0.953)	–	2 (0.593)	–	1 (0.521)	–	–

Strength of bilateral collaboration

To find the strength of bilateral collaboration, the number of collaborating linkages between the same pair of participating institutions was analysed. The results showed that bilateral collaboration was comparatively stronger under India–Bangladesh collaboration. It led to the publication of the following joint co-authored papers between the following Indian and Bangladeshi institutions: (i) Bangladesh University of Engineering and Technology (BUET), Dhaka and RRL, Bhubaneswar – 5 papers; (ii) BUET, Dhaka and IIT, Kharagpur – 4 papers; (iii) University of Dhaka and BHU, Varanasi – 3 papers; (iv) BHU, Varanasi and University of Rajshahi – 3 papers; (v) Society of Applied Sciences (SAS), Kolkata and International Center of Diarrhoeal Disease Research (ICDDR), Dhaka – 3 papers; and (vi) National Institute of Nutrition, Hyderabad and ICDDR, Dhaka – 3 papers. The India–Nepal and India-Pakistan collaboration was comparatively weaker, resulting in the following joint co-authored papers: (i) University College of Science and Technology, Kolkata and College of Medical Science, Chitawan – 3 papers, (ii) Himachal Pradesh University, Simla and International Centre of Integrated Mountain Development, Katmandu – 2 papers, (iii) Tribhuvan University, Applied Science and Technology Research Centre and IIT, New Delhi – 2 papers; and (iv) National Agricultural Research Centre, Pulses Programme, Islamabad and International Rice Research Institute, Liaison Office, New Delhi – 2 papers. Under India–Sri-Lanka collaboration, there were no significant linkages between the participating institutions.

Impact of geographical proximity on bilateral collaboration

The effect of geographical proximity on S&T collaborations revealed that under India–Bangladesh collaboration, there were 79 institutional collaborative linkages, among which 32 were between Bangladeshi institutions and Indian institutions located in West Bengal, and five were with institutions in Orissa. Both these regions are close to Bangladesh. The remaining collaborative linkages were spread over in nine other Indian states – Uttar Pradesh (18), Tamil Nadu (7), Maharashtra (4), Delhi (3), Andhra Pradesh (3) and Gujarat (3), Karnataka (2), Madhya Pradesh (1) and Bihar (1).

Similarly, the India–Nepal collaboration involved 14 institutional collaborative linkages among which two pertained to Bihar (Muzaffarpur and Arrah), two to Uttar Pradesh (Gorakhpur and Varanasi), and two to Himachal Pradesh (Simla), the regions that have geographical proximity with Nepal. Three collaborative linkages each were with institutions in West Bengal (Kolkata) and Delhi, and one each with institutions in Gujarat (Anand) and Andhra Pradesh (Patancheru). India-Pakistan collaboration involved six institutional collaborative linkages between Pakistani institutions and Indian institutions; two each were with institutions in Delhi and Ludhiana (Punjab) and one each in Hyderabad and Aligarh. The India-Sri Lanka collaboration involved six institutional linkages between Sri Lankan and Indian institutions; 2 each with institutions in Roorkee (UP) and Gandhi Nagar, and 1 each in Delhi and Patancheru.

Thus, geographical proximity did play an important role, except in the case of India–Sri Lanka, in undertaking collaborative research. This could be due to the following factors: (i) detailed information is known about the subject specialty of the scientists in the collaborating countries; (ii) more awareness about the availability of infrastructure facilities; (iii) higher confidence level about institutional credibility; and (iv) more friendly communication because of linguistic linkages.

Multilateral S&T collaborations of India with South Asian countries

Among the 83 multilateral co-authored papers, 78 involved the participation of India with at least one South Asian country, and one or more other countries outside the South Asia region. Five papers had the participation of India with two South Asian countries simultaneously and one or more other countries.

Among multilateral collaborative papers, the largest contribution (47 papers) was from India–Bangladesh, followed by India–Pakistan (17 papers), India–Nepal (15 papers) and India–Sri Lanka (9 papers).

Major priority subject areas and their impact under multilateral collaboration

The break up of 83 multilateral co-authored papers in seven major disciplines during 1992–99 is given in Table 6 along with their average IF values. The larger number of joint co-authored papers was published in clinical medicine, physics, biology and biomedical research. A break-up of these collaborative papers under various subfields is described below.

The 34 multilateral co-authored papers in clinical medicine were spread in 11 sub-disciplines, with major focus on general and internal medicine (13 papers), immunology (6 papers), ophthalmology (3 papers), and pharmacology (3 papers). The 16 papers in physics were in four sub-disciplines: general physics (9 papers), optics (4 papers), applied physics (2 papers), and nuclear and particle physics (1 paper). The 15 papers in biology were in 3 sub-disciplines: agricultural and food science (6 papers), botany (6 papers), and entomology (1 paper). The nine collaborative papers under biomedical research were in three sub-disciplines: microbiology (5 papers), nutrition and dietetics (3 papers), and genetics and heredity (1 paper). The six papers in earth and space sciences were in four sub-disciplines: earth and planetary science

Table 6. Major areas of multilateral collaboration with output of papers and their average IF values

Collaboration	Total number of papers	Number of papers with average IF (in parentheses) in different subjects						
		Physics	Clinical medicine	Biology	Earth and space sciences	Chemistry	Biomedical research	Health sciences
India–South Asia	83 (2.22)	16 (1.15)	34 (3.67)	15 (0.89)	6 (0.71)	2 (2.12)	9 (1.90)	1 (3.59)
India–Bangladesh	47 (2.39)	15 (1.20)	16 (4.41)	5 (0.74)	2 (0.96)	–	8 (1.82)	1 (3.59)
India–Nepal	15 (2.09)	–	8 (3.36)	6 (0.56)	1 (1.15)	–	–	
India–Pakistan	17 (1.70)	1 (0.33)	6 (3.14)	6 (0.75)	–	2 (2.12)	2 (1.50)	
India–Sri Lanka	9 (1.60)	–	5 (1.93)	1	3 (3.58)	–	– (0.39)	

(3 papers), environmental sciences (1 paper), geology (1 paper), and meteorology and atmospheric physics (1 paper).

The average value of IF per paper in multilateral papers was 2.22. The India–Bangladesh (47 papers) collaboration recorded the highest value of IF (2.39), followed by India–Nepal (2.09), India–Pakistan (1.70) and India–Sri Lanka (1.60).

The study also revealed that papers published under India–Bangladesh collaboration had higher impact (as revealed through IF values, Table 6) in the areas of clinical medicine, biomedical research and physics. The papers from the India–Nepal collaboration showed superiority in earth and space sciences, while the edge of India–Sri Lanka co-authored papers was in biology. The differences in IF values per paper were very large in three disciplines, viz. physics, biology and clinical medicine (Table 6).

Strength of multilateral collaboration

The strength of multilateral collaboration was found among participating institutions on the basis of joint co-authored papers and collaborative linkages. It was observed to be strongest under India–Bangladesh, with the following joint co-authored papers: (i) ICDDR, Dhaka and NICED, Kolkata (10 papers); ICDDR, Dhaka and SAS, Kolkata (8 papers); BUET, Dhaka and IIT, Kharagpur (4 papers), University of Dhaka and S. N. Bose National Centre for Basic Research, Kolkata (4 papers); and Rajshahi University and BHU, Varanasi (3 papers).

The strength of collaboration under India–Pakistan, India–Nepal and India–Sri Lanka was as follows: Bhabha Atomic Research Centre, Mumbai and Pakistan Institute of Nuclear Science and Technology, Islamabad (2 papers); Tribhuvan University, Institute of Agriculture and Animal Science and Indian Council of Agricultural Research, Cropping Systems Research, Meerut (3 papers); World Health Organization, Regional Office for South East Asia, New Delhi and University of Peradeniya, Colombo (2 papers) and IIT, New Delhi and Mihindu Keerthairatne Associates Ltd., Colombo (2 papers).

Number of countries participating per paper in multilateral collaboration

A total of 58 countries participated in multilateral collaborated papers, among which 53 countries were from outside South Asia. These countries participated in various combinations, ranging from 3 to 25. Around 54% of the multilateral collaborative research papers emanated from the team efforts of three countries. The participating teams comprising 11 to 25 countries accounted for about 7% of the total multilateral papers.

Among these papers, there was a noticeable involvement of international and regional organizations/centres, such as World Health Organization, Switzerland (7 papers), International Center for Agricultural Research in Dry Areas, Aleppo, Syria (6 papers), International Center for Theoretical Physics, Trieste, Italy (5 papers), and International Rice Research Institute, Manila, Philippines (2 papers), Forest Research Development Centre, SE Asian Regional Programme, Bogor, Indonesia (2 papers), UNICEF, New York (1 paper) and International Atomic Energy Agency, Vienna, Austria (1 paper). There was also an active involvement of international organizations located in South Asian countries, such as ICDDR, Dhaka (18 papers), World Health Organization, Regional Office for South East Asia, New Delhi (2 papers), ICRISAT, Patancheru (1 paper) and International Center for Integrated Mountain Development, Katmandu (1 paper).

The influence of different regions and countries on the extent of collaborations, measured by the number of countries participating in each paper was also analysed. USA had participated in maximum 33 (39.75%) papers, followed by UK 15 (18.07%) papers, Japan 14 (16.87%) papers, Italy and Indonesia 11 (13.25%) papers each, Thailand 10 (12.05%) papers, Germany 9 (10.84%) papers, Brazil 7 papers, Philippines and Sweden 6 papers each, Malaysia, Syria and Australia 5 papers each, and Canada and Nigeria 4 papers each, The Netherlands, Taiwan, South Korea and Mexico 3 papers each.

Institutional participation per paper in multilateral S&T collaboration

The number of institutions collaborating per paper from various participating countries in multilateral papers ranged from 3 to 55. The participation of three institutions was in more than 35% of the total papers. On the other hand, participation of 11 to 55 institutions accounted for 13.25% of all papers. Only in one multilateral paper, the number of participating institutions was 55. The number of participating institutions was less than 21 in other papers.

Areas for future cooperation

There are many areas of S&T where cooperation among South Asia countries would be mutually beneficial. These include food and fermentation technology, ore processing, metallurgy, glass and ceramics, paints and plastics, fine chemicals and leather. Other common areas could be: utilization of common eco-system, preserving a region's rich genetic biodiversity, hydropower resources and transmission of the generated electricity; maintaining surveillance on seismic, climatic and other environmental changes for sending advance warning against drought, flood and other environmental changes; undertaking joint

space programmes for the survey of natural resources and sharing of traditional knowledge in different subject areas. In addition, complimentary technological relations are necessary to sustain commercial relations, recognizing that technology would dominate the development challenges in the 21st century. A SAARC study group on economic cooperation has also prescribed regional technological cooperation to meet the requirement of global competitiveness. India – contributing 78% of the total manufacturing value in the region – has an unmistakable technological superiority in both capital and intermediate technology. Compared to Western technologies, India's expertise would be more suitable to South Asian countries.

Conclusions

A study on S&T collaboration of India with four South Asian countries (Bangladesh, Pakistan, Nepal and Sri Lanka) has been presented through the analysis of joint co-authored research papers published during 1992–99 in journals covered by *SCI*. As an outcome of these collaborations, a total of 178 joint co-authored papers were published, 95 under bilateral collaborations and 83 under multilateral collaborations. In all, 154 institutions were involved in these collaborations, among which 61 were from India, 32 from Bangladesh, 27 from Pakistan, 21 from Nepali and 7 from Sri Lanka. In India, IIT, Kharagpur tops the list with 15 collaborative papers, followed by BHU, Varanasi and NICED, Kolkata (10 papers each). Amongst India's collaborations with fellow South Asian countries, India–Bangladesh joint collaborative research produced maximum number of papers through bilateral (71 papers) as well as multilateral (47 papers) research. The most favourite area for collaboration has been found to be 'clinical medicine', both in terms of joint research output and citation impact, probably because of marked growth in research in health-related problems the world over and application of these research results for solving environmental health hazards during the last decade. USA, as expected had the maximum share amongst participating countries outside the South Asian arena in all co-authored papers. The study has revealed that geographical proximity also plays a significant role in these collaborations, probably because of close awareness about institutions and scientists from the neighbouring countries, and also cultural and linguistic connections. The need for further cooperation has been indicated in areas such as biotechnology, biodiversity, environment, floods and droughts and above all, in traditional knowledge on medicine and health care of the region.

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