

Scientometric analysis of Pakistan's S&T research output

B. M. Gupta

Emeritus Scientist, CSIR-National Institute of Science, Technology & Development Studies, Dr K.S. Krishnan Marg,
New Delhi 110012, India, Email: bmguptal@gmail.com

Received 14 December 2011, revised 14 March 2012

The study analyses the research output of Pakistan for the period 2001-10 on several parameters including its growth and share in the world's research output, pattern of research communication in core domestic and international journals, geographical distribution of publications, share of international collaborative publications at the national level as well as across subjects and characteristics of high productivity institutions, authors and cited papers. The Scopus citation database has been used to retrieve the publications data for 10 years. Concludes that Pakistan needs to increase its output and bring about improvement in the quality of its research efforts. This can be done by investing much more in R&D expenditure, increase in the deployment of more qualified manpower and in increasing international collaboration and by modernizing and strengthening its research infrastructure.

Keywords: Scientometrics, Pakistan, Research output

Introduction

Science and Technology (S&T) has been central to Pakistan's development efforts since the time of its Independence. At the time of independence, the scientific and the technological base of the country was very small and consisted of only 4 small laboratories, two universities and one agricultural college. But today it consists of a wide spectrum of infrastructure in terms of laboratories, R&D institutions, in-house R&D establishments' etc., covering several disciplines. For policy formulation at the national level, there is a National Commission for Science & Technology (NCST) (established in 1984) under the Prime Minister. There is a Pakistan Council for Science & Technology (PCST) which advises the government on science and technology policies and act as a Secretariat of the NCST. For policy formulation at the sectoral level, there are ministries of Science & Technology, IT & Telecom, Agriculture, Health, Industries, Higher Education Commission and Pakistan Atomic Energy Commission¹.

Pakistan's S&T infrastructure today consists of 85 major R&D organizations with 224 attached research institutes, centres and laboratories (35 under federal governments and 50 under provincial governments) and 133 universities, including 17 in engineering &

technology, 6 in agriculture and 9 in medical science and technology, 28 in business/IT, besides 2000 affiliated colleges. The total S&T workforce in Pakistan is around 1,37,220 during 2009-10. Out of this, the total number of researchers and scientists is 54,689, but only 10% (5300) of these hold PhD in S&T. Eighty percent of these PhDs are employed in higher education institutions. Of the 54,689 researchers and scientists in Pakistan, 12,896 are in natural sciences, 9651 in engineering, 8509 in medical sciences, 8020 in agricultural sciences, etc. Its present stock consists of 54,689 researchers, which comes to 334 researchers per million and 169 researchers per million (FTE). The growth of R&D expenditure as a percentage of GDP has increased from 0.11% in 1999-2000 to 0.46% in 2008-09¹.

Although the gross primary school education rates were 84.8% in 2008 (World Bank), but only 32.9% of the Pakistani children are receiving secondary education and around 5% are enrolled for tertiary education. Currently, 7% to 8% of the 17-23 age group have access to higher education in Pakistan, increasing from 2.6% eight years ago. The enrollment of students in universities & colleges in the age group of 17-23 has increased from 2.6% in 2002 to 5.1% in 2009².

Pakistan has made an investment of more than Rs. 97 billion for the development of universities since the formation of Higher Education Commission in 1992, a twelve-fold increase over the Rs 7.5 billion spent during 1978-2002³.

As a result, the number of universities has increased from 98 to 133 and enrollment from 1,35,000 in 2003 to 8,03,507 in 2008. Since HEC founding, 3509 PhDs have been produced, 200 more than the 3309 produced in the 55 years earlier. Currently, HEC is funding 7500 scholars for PhD at both local and foreign universities. The number of PhDs awarded by the Pakistani universities is currently 700 per year⁴.

A few scientometric studies on Pakistan's research output are available. Among these studies, Mehbuba and Rousseau⁵ has compared Bangladesh, Pakistan and Sri Lanka research output with India using three indicators, such as percentage of uncited articles, number of citations per document and *h*-index. Gupta, Munshi and Mishra⁶ analysed India's collaboration with South Asian countries during 1992-99 using SCI database. Naim⁷ mapped scientific research in OIC countries (including Pakistan and Bangladesh), using the indicators such as human resources in R&D, R&D expenditure, high technology exports, patents and publications. Under publications, trends in publications and relative impact of research in terms of citations during 1998-2007 have been undertaken. Majid⁸ analysed the trends in Pakistan agricultural research by analyzing papers in ten volumes of *Pakistan Journal of Agricultural Research*. However, there has been no detailed study on the Pakistan's scientific output so far and hence this study was undertaken.

Objectives of the study

- To analyze Pakistan's research publications growth rate and its share in global R&D output;
- To identify the most, medium, low and least productive areas of research;
- To find the share of international collaborative papers and identification of major collaborative partners; and
- To understand characteristics of its highly productive institutions, authors and highly cited papers.

Methodology

This study uses Scopus international database (<http://www.scopus.com/search/>) to extract relevant publications data on Pakistan S&T for the 10 year period (2001-10). Scopus database is an international multi-disciplinary database indexing over 18,000 titles from more than 5,000 publishers, including 16,500 peer-reviewed journals, 600 trade publications, 350 book series and 3.6 million international conference/seminar papers. Scopus has a worldwide coverage, of which more than half of the Scopus contents originate from Europe, Latin America and the Asia & the Pacific Region. Given its wider coverage of journals and conference/seminar proceedings from developed and developing countries (including from Pakistan) compared to another international multidisciplinary database, Web of Science, the use of Scopus is expected to generate a better picture of Pakistan S&T indicators and hence its selection for this study.

For citations data, three years, two years and one year citations window have been used for computing average citations per paper during 2001-08, 2009 and 2010. For example, for papers published in 2001, citation window is three years from 2001-04. For papers published in 2002, citation window is three years from 2002-2005 and so on. For calculating the total international collaborative papers, a separate search strategy, which combines Pakistan's collaboration with more than 150 major countries, was prepared and used. For analyzing institutional, authors and journals output, separate search strategies were used. For generating highly-cited papers, the main string is first run. Then, the tag "citation to" is ticked, which rearranges the entire output in the decreasing order of citations received by each paper with most cited papers at the top. Then these highly-cited papers are marked and downloaded for analyses. The study has used a number of absolute publications, citation and collaborative measures for developing S&T indicators as needed for depicting Pakistan's status in science and technology from 2001 to 2010.

Analysis

S&T publications output

Pakistan has produced 34,195 papers during the last ten years (2001-10), which is increasing at an annual average growth rate of 20.86%. As per the Scopus data, cumulative publications growth, the cumulative S&T publications output of Pakistan had increased

from 8981 publications during 2001-05 to 25,214 publications during 2006-10, experiencing a growth rate of 180.75% (Table 1). The *h*-index of its total publications during 2001-10 was 85 and the number of highly-cited papers recorded was 64. Its average citation impact on a three year citation window for its total publications during 2001-10 was 2.19. The global publications share of Pakistan during 2001-10 was 0.196, which has increased from 0.099 in 2001 to 0.328 in 2010 (Table 2). This growth could also be on account of increased coverage of journals in the Scopus database over the years.

Subject profile in science & technology

As per the publications data for 2001-10, Pakistan's research profile by broad disciplines emerges as follows. Health sciences subjects together contributed

the highest publications share (32.10%), followed by physical sciences (30.15%), life sciences (27.04%) and engineering sciences (26.04%). Its publications share has increased in physical sciences from 25.75% to 31.72%, engineering sciences from 18.41% to 28.76% and life sciences from 23.85% to 28.17%, as against decrease in health sciences from 40.20% to 29.22% from 2001-05 to 2006-10 (Table 3).

High productivity subject areas

Medicine, agricultural & biological sciences, engineering, chemistry and physics have been identified as the five high priority areas of Pakistan in S&T with each contributing publication share between 10.76% and 30.85% in the cumulative national publication output of Pakistan during 2001-10 (Table 4).

Table 1—Pakistan's research output

Year	TP	ACPP	ICP	ICP share (%)
2001	1318	1.76	248	18.82
2002	1464	1.77	275	18.78
2003	1583	2.67	465	29.37
2004	1977	2.62	507	25.64
2005	2639	2.63	634	24.02
2006	3288	2.95	873	26.55
2007	3920	3.42	1132	28.88
2008	4910	3.24	1424	29.00
2009	5960	1.81	1701	28.54
2010	7136	0.52	2243	31.43
2001-05	8981		2129	23.71
2006-10	25214		7373	29.24
2001-10	34195	2.19	9502	27.79

TP=Total Papers; ACPP=Average Citations per Paper; ICP=International Collaborative Papers

Table 2—Pakistan's publication share in world literature

Year	Count of papers		Pakistan's share(%)
	Pakistan	World	
2001	1318	1326979	0.099
2002	1464	1371936	0.107
2003	1583	1426444	0.111
2004	1977	1579618	0.125
2005	2639	1749574	0.151
2006	3288	1832242	0.179
2007	3920	1927447	0.203
2008	4910	2006228	0.245
2009	5960	2087381	0.286
2010	7136	2175243	0.328
2001-10	34195	17483092	0.196

Table 3—Distribution of papers by broad subjects

Broad subjects	Number of papers			Publications share (%)*		
	2001-05	2006-10	2001-10	2001-05	2006-10	2001-10
Physical Sciences	2313	7997	10310	25.75	31.72	30.15
Engineering Sciences	1653	7252	8905	18.41	28.76	26.04
Life Sciences	2142	7103	9245	23.85	28.17	27.04
Health Sciences	3610	7367	10977	40.20	29.22	32.10

*There are overlapping journals under physical, engineering, life and health sciences

Table 4—High productivity subject areas

Subject	National publication share (%)			World publication share (%)	ICP share (%)	ACPP	h-index	HCP
	2001-05	2006-10	2001-10					
Medicine	39.15	27.89	30.85	0.222	18.66	2.00	56	20
Agricultural & Biol. Sciences	14.12	18.07	17.03	0.493	24.46	2.04	39	7
Engineering	10.81	13.53	12.81	0.115	30.69	1.72	38	9
Chemistry	12.70	12.63	12.65	0.331	36.29	2.44	39	5
Physics	6.40	12.31	10.76	0.190	50.72	3.09	38	6

ACPP=Average Citations per Paper; ICP=International Collaborative Papers; HCP=Highly Cited Papers

The highest national publication share of Pakistan in medicine was 30.94%, followed by agricultural & biological sciences (17.03%), engineering (12.81%), chemistry (12.65%) and physics (10.76%). The national publication share of Pakistan has witnessed the largest increase in physics by 5.91% (from 6.40% to 12.31%), agricultural & biological sciences by 3.95% (from 14.12% to 18.07%) and engineering by 11.26% in medicine (from 39.15% to 27.89%) from 2001-05 to 2006-10. The highest global publications share (0.493%) of Pakistan in these high productivity subject areas was observed in agricultural & biological sciences, followed by chemistry (0.331%), medicine (0.222%), physics (0.190%) and engineering (0.137%) during 2001-10. The largest international collaborative publications share (50.72%) of Pakistan was observed in physics, followed by chemistry (36.29%), engineering (30.69%), agricultural & biological sciences (24.46%) and medicine (18.66%) during 2001-10 (Table 4).

The highest average citation impact per paper (3.09) for all its publications in high productivity subject areas was observed in physics, followed by chemistry (2.44), medicine (2.09), agricultural & biological sciences (2.04) and engineering (1.72) during 2001-10. The highest *h*-index (56) of Pakistan publications during 2001-10 was achieved by medicine, followed

by agricultural & biological sciences and chemistry (39 each) and engineering and physics (38 each) during 2001-10. The largest number of highly-cited papers (20) was recorded by Pakistan in medicine, followed by engineering (9), agricultural & biological sciences (7), physics (6) and chemistry (5) during 2001-10 (Table 4).

Medium productivity subject areas

Computer science, biochemistry, genetics & molecular biology, materials science, mathematics, pharmacology, toxicology & pharmaceuticals and environmental science are considered as the six medium priority areas of Pakistan in S&T, each contributing publication share between 3.80% and 9.62% in the cumulative national publication output of Pakistan during 2001-10 (Table 5).

The highest national publication share (9.62%) of Pakistan was recorded in computer science, followed by biochemistry, genetics & molecular biology (8.43%), materials science (6.64%), mathematics (5.51%), pharmacology, toxicology & pharmaceuticals (3.80%) and environmental science (3.80%) during 2001-10. The national publication share of Pakistan has witnessed the largest increase in computer science by 9.39% (from 2.69% to 12.08%), materials science by 4.90% (from 3.03% to 7.92%), mathematics by

4.43% (from 2.24% to 6.67%), biochemistry, genetics & molecular biology by 2.15% (from 6.84% to 8.99%) and environmental science by 0.64% (from 3.33% to 3.97%), as against decrease in pharmacology, toxicology & pharmaceuticals by 0.24% (from 3.98% to 3.74%) from 2001-05 to 2006-10. The highest global publications share (0.232%) of Pakistan in these medium productivity subject areas was observed in computer science, followed by mathematics (0.220%), pharmacology, toxicology & pharmaceuticals (0.209%), environmental science (0.185%), materials science (0.159%) and biochemistry, genetics & molecular biology (0.138%) during 2001-10. The largest international collaborative publications share (47.59%) of Pakistan was observed in biochemistry, genetics & molecular biology, followed by materials science (47.09%), mathematics (44.18%), pharmacology, toxicology & pharmaceuticals (36.92%), environmental science (36.72%) and computer science (30.69%) during 2001-10 (Table 5).

The highest average citation impact per paper (4.02) for all its publications in medium productivity subject areas was observed in environmental science, followed by biochemistry, genetics & molecular biology (3.99), pharmacology, toxicology & pharmaceuticals (3.44), mathematics (2.61), materials science (2.18) and computer science (0.66) during 2001-10. The highest *h*-index (51) of Pakistan publications was achieved by biochemistry, genetics & molecular biology in 2001-10, followed by pharmacology, toxicology & pharmaceuticals (33), environmental science (32), mathematics (30), materials science (25) and computer science (18)

during 2001-10. The largest number of highly-cited papers (13) was recorded by Pakistan in biochemistry, genetics & molecular biology, followed by mathematics and environmental science (3 each) and computer science (1) during 2001-10 (Table 5).

Low productivity subject areas

Immunology & microbiology, chemical engineering, energy, earth & planetary sciences and nursing are found as the five low priority areas of Pakistan in S&T, each contributing publication share between 1.21% and 2.98% in the cumulative national publication output of Pakistan during 2001-10 (Table 6).

Among the low productivity subjects, the highest national publication share (2.98%) of Pakistan was recorded in immunology & microbiology, followed by chemical engineering (2.63%), energy (1.94%), earth & planetary sciences (1.80%) and nursing (1.21%) during 2001-10. The national publication share of Pakistan has witnessed the largest increase in chemical engineering by 0.91% (from 1.96% to 2.87%), nursing by 0.88% (from 0.57% to 1.44%), immunology & microbiology by 0.51% (from 2.61% to 3.11%) and energy by 0.12% (from 1.86% to 1.98%), as against decrease in earth & planetary sciences by 0.27% (from 1.99% to 1.73%) from 2001-05 to 2006-10. The highest global publications share (0.181%) of Pakistan in these low productivity subject areas was observed in immunology & microbiology, followed by energy (0.168%), nursing (0.156%), chemical engineering (0.115%) and earth & planetary sciences (0.082%) during 2001-10. The largest international collaborative publications share

Table 5—Medium productivity subject areas

Subject	National publication share (%)			World publication share (%)	ICP share (%)	ACPP	<i>h</i> -index	HCP
	2001-05	2006-10	2001-10					
Computer Science	2.69	12.08	9.62	0.232	30.69	0.66	18	1
Biochem., Genet. & Mol. Biology	6.84	8.99	8.43	0.138	47.59	3.99	51	13
Materials Science	3.03	7.92	6.64	0.159	47.09	2.18	25	0
Mathematics	2.24	6.67	5.51	0.220	44.18	2.61	30	3
Pharmacology, Toxicology & Pharmaceuticals	3.98	3.74	3.80	0.209	36.92	3.44	33	0
Environmental Science	3.33	3.97	3.80	0.185	36.72	4.02	32	3

ACPP=Average Citations per Paper; ICP=International Collaborative Papers; HCP=Highly Cited Papers

(51.79%) of Pakistan was observed in earth & planetary sciences, followed by immunology & microbiology (38.96%), chemical engineering (35.15%), nursing (22.41%) and energy (19.10%) during 2001-10 (Table 6).

The highest average citation impact per paper (4.97) for all its publications in low productivity subject areas was observed in immunology & microbiology, followed by chemical engineering (4.46), earth & planetary sciences (3.06), energy (2.36) and nursing (1.56) during 2001-10. The highest *h*-index (34) of Pakistan publications was achieved by immunology & microbiology in 2001-10, followed by energy (29), earth & planetary sciences (26), energy (21) and nursing (15) during 2001-10. The largest number of highly-cited papers (8) was recorded by Pakistan in immunology & microbiology, followed by chemical engineering and earth & planetary sciences (3 papers each) during 2001-10 (Table 6).

Least productivity subject areas

Veterinary science, neurosciences, public health and dentistry are found as the four productive subject

areas of Pakistan in S&T, each contributing publication share between 0.14% and 0.98% in the cumulative national publication output of Pakistan during 2001-10 (Table 7).

The highest national publication share (0.98%) of Pakistan was recorded in veterinary science, followed by neurosciences (0.53%), public health (0.43%) and dentistry (0.141%) during 2001-10. The national publication share of Pakistan has witnessed the largest increase in veterinary science by 0.39% (from 0.69% to 1.08%) and dentistry by 0.03% (from 0.12% to 0.15%), as against decrease in public health by 0.17% (from 0.56% to 0.39%) and neurosciences by 0.29% (from 0.75% to 0.46%) from 2001-05 to 2006-10. The highest global publications share (0.194) of Pakistan in these least productivity subject areas was observed in veterinary science, followed by public health (0.060), dentistry (0.051) and neurosciences (0.038) during 2001-10. The largest international collaborative publications share (60.42%) of Pakistan was observed in dentistry, followed by neurosciences (56.59%), public health (43.92%) and veterinary science (22.39%) during 2001-10 (Table 7).

Table 6—Low productivity subject areas

Subject	National publication share (%)			World publication share (%)	ICP share (%)	ACPP	<i>h</i> -index	HCP
	2001-05	2006-10	2001-10					
Immunology & Microbiology	2.61	3.11	2.98	0.181	38.96	4.97	34	8
Chemical Engineering	1.96	2.87	2.63	0.115	35.15	4.46	29	3
Energy	1.86	1.98	1.94	0.168	19.10	2.36	21	0
Earth & Planetary Science	1.99	1.73	1.80	0.082	51.79	3.06	26	3
Nursing	0.57	1.44	1.21	0.156	22.41	1.56	15	0

ACPP=Average Citations per Paper; ICP=International Collaborative Papers; HCP=Highly Cited Papers

Table 7—Least productivity subject areas

Subject	National publication share (%)			World publication share (%)	ICP share (%)	ACPP	<i>h</i> -index	HCP
	2001-05	2006-10	2001-10					
Veterinary Science	0.69	1.08	0.938	0.194	22.39	2.05	15	0
Neurosciences	0.75	0.46	0.53	0.038	56.59	4.47	17	0
Public Health	0.56	0.39	0.43	0.060	43.92	3.87	18	0
Dentistry	0.12	0.15	0.14	0.051	60.42	2.81	7	0

ACPP=Average Citations per Paper; ICP=International Collaborative Papers; HCP=Highly Cited Papers

The highest average citation impact per paper (4.47) for all its publications in low productivity subject areas was observed in neurosciences, followed by public health (3.87), dentistry (2.81) and veterinary science (2.05) during 2001-10. The highest *h*-index (18) of Pakistan publications was achieved by public health in 2001-10, followed by neurosciences (17), veterinary science (15) and dentistry (7) during 2001-10. The number of highly-cited papers recorded by Pakistan in all the four subjects was zero each during 2001-10 (Table 7).

International collaboration

The share of international collaborative papers in the Pakistan research output was 27.79% during 2001-10. Its share of internationally collaborative papers has increased from 23.71% during 2001-05 to 29.24% during 2006-10. In terms of citation impact of international collaborative papers, Pakistan has achieved a citation impact of 3.93 per paper during 2001-10. Table 8 depicts the international collaborative linkages of Pakistan with top 45 countries during 2001-10. The largest number of collaborative linkages (2243) of Pakistan was with United States with 23.61% share, followed by United Kingdom (20.23% share), Germany (9.75% share), China (9.02% share), Canada, Japan, Saudi Arabia, South Korea, India, Australia, Italy, France and Malaysia (with share varying from 3.14% to 6.69%), Turkey, Switzerland, Sweden, Iran, Austria and South Africa (with share varying from 2.07% to 2.98%), Netherlands, Spain, Russia, Brazil, Bangladesh, Egypt, Romania, Mexico, Singapore, Kuwait, Thailand, New Zealand, Belgium and Poland (with share varying from 1.01% to 1.77%). Of the top 45 international collaborating countries, Pakistan collaborative linkages have decreased in 16 countries, with largest decrease seen in authorship with United States by 8.08%, followed by UK (5.29%), Japan (2.38%), Italy (1.06%), Sri Lanka (0.54%), Nepal (0.36%), Australia (0.33%), Bangladesh (0.33%), Canada (0.27%), Germany (0.21%), Columbia (0.20%), Singapore (0.17%), Argentina (0.17%), Thailand (0.13%), France (0.09) and Jordan (0.04%) from 2001-05 to 2006-10. In contrast, Pakistan collaborative linkages has increased with 29 other countries, with maximum increase of 6.90% with China, followed by South Korea (2.72%), Sweden (1.54%), Austria (1.23%), Turkey (1.11%), New Zealand (1.05%), South Africa (1.04%) and less than

1% in other 22 countries from 2001-05 to 2006-10 (Table 8).

On further grouping 45 collaborating countries and individual country share, it was found that Pakistan's combined collaborating papers share was highest (73.26%) with G-8 countries, followed by 18 developing countries (39.01% share), 13 European countries (19.46% share), 4 South Asian countries (6.82% share), and 2 Pacific countries (4.98%) during 2001-10. Among these five group of countries, Pakistan's combined collaborating papers share has decreased by 16.45% with G-8 countries and by 0.72% with South Asian countries, as against increase by 17.36% with developing countries, 8.39% with European countries and 0.72% with Pacific countries from 2001-05 to 2006-10. Here the combined share of 45 collaborating countries is more than 100 per cent, because in each international collaborative paper from Pakistan, there are one or more than one collaborating countries (Table 8).

Geographical distribution of papers

Islamabad, Karachi and Lahore are the three most productive geographical areas in Pakistan who have individually contributed 17.46% to 26.64% share individually (together 70.58%) to the total research output of Pakistan during 2001-10. The cumulative number of papers has increased in Islamabad by 5.29% (from 22.74% to 28.03%) and in Lahore by 3.99% (from 14.52% to 18.51%), as against decrease in Karachi by 12.62% (from 35.79% to 23.17%) from 2001-05 to 2006-10 (Table 9).

Faisalabad, Rawalpindi, Peshwar, Multan and Jamshoro are the five medium productive geographical areas with their individual publication share between 2.68% and 7.96%, (together 28.28%) to the total research output of Pakistan during 2001-10. The cumulative number of papers has increased in Faisalabad by 3.26% (from 5.56% to 8.81%), in Rawalpindi by 1.25% (from 6.50% to 7.75%), in Jamshoro by 1.08% (from 1.88% to 2.96%) and in Multan by 0.64% (from 2.75% to 3.39%), as against decrease in Peshawar by 0.52% (from 7.37% to 6.85%) from 2001-05 to 2006-10 (Table 9).

Sargodha, Bahawalpur, Abbottabad, Quetta and Topi are the five low productive geographical areas with their individual publication share between 1.18% and 1.83% (together 7.40%) to the total research output of Pakistan during 2001-10. The cumulative number of

Table 8—Pakistan's collaboration with top 45 countries

Sl. no.	Collaborating country	Number of collaborative papers			Share of collaborative papers		
		2001-05	2006-10	2001-10	2001-05	2006-10	2001-10
1.	USA	636	1607	2243	29.87	21.80	23.61
2.	UK	518	1404	1922	24.33	19.04	20.23
3.	Germany	211	715	926	9.91	9.70	9.75
4.	China	78	779	857	3.66	10.57	9.02
5.	Canada	147	489	636	6.90	6.63	6.69
6.	Japan	159	375	534	7.47	5.09	5.62
7.	Saudi Arabia	101	416	517	4.74	5.64	5.44
8.	S.Korea	68	436	504	3.19	5.91	5.30
9.	India	86	300	386	4.04	4.07	4.06
10.	Australia	87	277	364	4.09	3.76	3.83
11.	Italy	91	237	328	4.27	3.21	3.45
12.	France	75	253	328	3.52	3.43	3.45
13.	Malaysia	58	240	298	2.72	3.26	3.14
14.	Turkey	45	238	283	2.11	3.23	2.98
15.	Switzerland	61	221	282	2.87	3.00	2.97
16.	Sweden	25	200	225	1.17	2.71	2.37
17.	Iran	34	190	224	1.60	2.58	2.36
18.	Austria	26	181	207	1.22	2.45	2.18
19.	S.Africa	27	170	197	1.27	2.31	2.07
20.	Netherlands	36	132	168	1.69	1.79	1.77
21.	Spain	20	132	152	0.94	1.79	1.60
22.	Russia	16	123	139	0.75	1.67	1.46
23.	Brazil	22	113	135	1.03	1.53	1.42
24.	Bangladesh	35	97	132	1.64	1.32	1.39
25.	Egypt	15	118	133	0.70	1.60	1.40
26.	Romania	15	116	131	0.70	1.57	1.38
27.	Mexico	19	108	127	0.89	1.46	1.34
28.	Singapore	29	88	117	1.36	1.19	1.23
29.	Kuwait	15	99	114	0.70	1.34	1.20
30.	Thailand	27	84	111	1.27	1.14	1.17
31.	New Zealand	7	102	109	0.33	1.38	1.15
32.	Belgium	14	83	97	0.66	1.13	1.02
33.	Poland	15	81	96	0.70	1.10	1.01
34.	Finland	8	75	83	0.38	1.02	0.87
35.	Taiwan	14	68	82	0.66	0.92	0.86
36.	Sri Lanka	26	50	76	1.22	0.68	0.80
37.	Czech Republic	9	56	65	0.42	0.76	0.68
38.	Philippines	12	47	59	0.56	0.64	0.62
39.	Columbia	16	41	57	0.75	0.56	0.60
40.	Nepal	18	36	54	0.85	0.49	0.57
41.	Nigeria	3	48	51	0.14	0.65	0.54
42.	Ukraine	2	44	46	0.09	0.60	0.48
43.	Argentina	12	29	41	0.56	0.39	0.43
44.	Jordan	9	28	37	0.42	0.38	0.39
45.	Slovenia	0	14	14	0.00	0.19	0.15
	Total*	2129	7373	9502	100.00	100.00	100.00

*Total collaborative papers of Pakistan. In all international collaborative papers of Pakistan, there are one or more foreign collaborating countries. As a result, the combined output of 45 collaborative countries listed above in Pakistan international collaborative output will be more than its total international collaborative papers

papers has increased in Sargodha by 1.95% (from 0.39% to 2.34%), in Bahawalpur by 0.74% (from 1.20% to 1.95%), in Abbottabad by 0.39% (from 1.04% to 1.43%) and in Topi by 0.10% (from 1.10% to 1.20%), as against decrease in Quetta by 0.28% (from 1.53% to 1.25%) from 2001-05 to 2006-10 (Table 9).

Institutional profile

Universities

The top 28 universities in Pakistan together have published 17,738 papers, which account for 51.87% share of the total research output of Pakistan during 2001-10. The output of individual universities, however, varied from 82 to 3355, with an average productivity of 700 papers per organization. The international collaborative share of these 28 universities account for 30.66% share (varying from 8.98% to 55.77%) of their total output during 2001-10. These 28 universities have an *h*-index of 65 (varying from 5 to 44) and number of highly-cited papers was only 32 (varying from 0 to 12). A complete profile of these 28 universities is given in Table 10.

Research institutes

The top 14 research institutes in Pakistan together have published 5942 papers, which account for 17.30% share of the total research output of Pakistan during 2001-10. The output of individual research institutes, however, varied from 67 to 1137, with an average productivity of 447.36 papers per organization. The international collaborative share of these 14 research institutes account for 27.52% share (varying from 15.00% to 46.62%) of their total output during 2001-10. These 14 research institutes have an *h*-index of 49 (varying from 6 to 32) and number of highly-cited papers published was only 18 (varying from 0 to 9). A complete profile of these 14 research institutes is given in Table 11.

Medical colleges & hospitals

The top 18 medical colleges & hospitals in Pakistan together have published 4890 papers, which account for 14.30% share of the total research output of Pakistan during 2001-10. The output of individual medical colleges & hospitals, however, varied from 100 to 1575, with an average productivity of

Table 9—Geographical distribution of papers

City	Number of papers			Share of papers		
	2001-05	2006-10	2001-10	2001-05	2006-10	2001-10
Islamabad	2042	7067	9109	22.74	28.03	26.64
Karachi	3214	5842	9056	35.79	23.17	26.48
Lahore	1304	4667	5971	14.52	18.51	17.46
Faisalabad	499	2222	2721	5.56	8.81	7.96
Rawalpindi	584	1956	2540	6.50	7.76	7.43
Peshwar	662	1728	2390	7.37	6.85	6.99
Multan	247	854	1101	2.75	3.39	3.22
Jamshoro	169	747	916	1.88	2.96	2.68
Sargodha	35	591	626	0.39	2.34	1.83
Bahawalpur	108	491	599	1.20	1.95	1.75
Abbottabad	93	360	453	1.04	1.43	1.32
Quetta	137	314	451	1.53	1.25	1.32
Topi	99	303	402	1.10	1.20	1.18
Taxila	52	271	323	0.58	1.07	0.94
Hyderabad	42	208	250	0.47	0.82	0.73
Kohat	9	180	189	0.10	0.71	0.55
Dera Ismail Khan	42	117	159	0.47	0.46	0.46
Muzaffarabad	33	124	157	0.37	0.49	0.46
Mansehra	2	114	116	0.02	0.45	0.34
Total*	8981	25214	34195	100.00	100.00	100.00

*Total output of Pakistan. The total publications output of Pakistan cities listed above is more than the total publication output of Pakistan. This is because of the presence of national collaborative papers, where there are two or more authors involved from two different Pakistan cities.

Table 10—Top 28 most productive universities of Pakistan

Sl. no.	University	TP	<i>h</i> -index	HCP	ICP	ICP Share
1	Quaid-i-Azam University, Islamabad	3355	43	12	1314	39.17
2	University of Karachi	2792	31	0	772	27.65
3	The Aga Khan University, Karachi	1751	44	12	555	31.70
4	University of Punjab, Lahore	1747	29	3	500	28.62
5	National University of Science and Technology, Rawalpindi	1327	18	1	421	31.73
6	Government College University, Lahore	1096	23	0	381	34.76
7	University of Engineering & Technology, Lahore	865	13	0	279	32.25
8	University of Peshawar	805	21	3	224	27.83
9	Bahauddin Zakariya University, Multan	715	24	1	209	29.23
10	University of Sindh, Jamshoro	581	23	0	108	18.59
11	University of Sargodha	562	13	0	163	29.00
12	Islamia University, Bahawalpur	445	20	0	114	25.62
13	University of Arid Agriculture, Rawalpindi	438	14	0	98	22.37
14	International Islamic University, Islamabad	361	9	0	82	22.71
15	NWFP Agricultural University, Peshawar	426	15	2	120	28.17
16	Gomal University, Dera Ismail Khan	258	11	0	56	21.71
17	University of Balochistan, Quetta	247	12	0	74	29.96
18	Mohammad Ali Jinnah University, Islamabad	243	8	0	44	18.11
19	University of Veterinary & Animal Sciences, Lahore	216	10	0	62	28.70
20	NED University of Engineering & Technology, Karachi	191	7	0	47	24.61
21	National University of Computer & Emerging Sciences, Islamabad	180	6	0	24	13.33
22	Kohat University of Science & Technology (KUST), Kohat	156	5	0	87	55.77
23	Hamdard University, Karachi	167	10	0	15	8.98
24	University of Agriculture, Faisalabad	172	12	0	47	27.33
25	University of Azad Jammu & Kashmir, Muzaffarabad	155	8	0	40	25.81
26	Sindh Agricultural University, Tando Jam	136	7	0	24	17.65
27	Allama Iqbal Open University, Islamabad	151	9	0	66	43.71
28	Mehran University of Engineering & Technology, Jamshoro	82	5	0	36	43.90

TP=Total Papers; ICP=International Collaborative Papers; HCP=Highly Cited Papers

283.55 papers per organization. The international collaborative share of these 18 medical colleges & hospitals account for 13.13% share (varying from 2.91% to 24.02%) of their total output during 2001-10. These 18 medical colleges & hospitals have an *h*-index of 39 (varying from 7 to 28) and number of highly-cited papers published was only 3 (varying

from 0 to 1). A complete profile of these 18 medical colleges & hospitals is given in Table 12.

Contribution and citation impact of most productive authors

Fifteen authors have been identified as productive authors who have published 106 and above papers in

Table 11—Pakistan's top 14 most productive research institutes

Sl. no.	Research institute	TP	<i>h</i> -index	HCP	ICP	% ICP
1	Pakistan Institute of Nuclear Science & Technology, Islamabad	1137	32	3	241	21.20
2	COMSATS Institute of Information Technology, Islamabad	1229	27	3	573	46.62
3	PCSIR Laboratories, Peshawar	823	24	1	209	25.39
4	National Agricultural Research Center, Islamabad	511	18	1	127	24.85
5	Pakistan Institute of Engineering & Applied Sciences, Islamabad	559	17	0	140	25.04
6	Nuclear Institute for Agriculture & Biology, Faisalabad	428	13	0	80	18.69
7	National Institute of Biotechnology & Genetic Engineering, Faisalabad	392	32	9	133	33.93
8	Ghulam Ishaq Khan Institute of Engineering Science & Technology, Topi	383	17	0	148	38.64
9	Center for Advanced Studies in Engineering, Islamabad	204	6	0	34	16.67
10	Pakistan Institute of Medical Sciences, Islamabad	174	13	1	27	15.52
11	Pakistan Atomic Energy Commission, Islamabad	148	13	1	38	25.68
12	Nuclear Institute for Food & Agriculture, Peshawar	120	8	0	18	15.00
13	National Institute of Health, Islamabad	88	13	0	25	28.41
14	Dr A.Q. Khan Research Laboratories, Rawalpindi	67	13	1	18	26.87

TP=Total Papers; ACP=Average Citation Per Paper; ICP=International Collaborative Papers; HCP=Highly Cited Papers

Table 12—Pakistan's top 18 most productive medical colleges & hospitals

Sl. no	Medical colleges & hospitals	TP	<i>h</i> -index	HCP	ICP	%ICP
1	The Aga Khan University Hospital, Karachi	1575	28	1	263	16.70
2	Jinnah Postgraduate Medical Center, Karachi	333	12	0	32	9.61
3	Liaquat National Hospital, Karachi	282	13	0	34	12.06
4	Dow Medical College, Karachi	165	11	0	19	11.52
5	Dow University of Health Sciences, Karachi	313	10	0	38	12.14
6	Liaquat University of Medical & Health Sciences, Jamshoro	315	9	0	33	10.48
7	King Edward Medical University, Lahore	329	18	1	40	12.16
8	Khyber Medical College, Peshawar	215	9	0	8	3.72
9	The Aga Khan University Medical College, Karachi	179	19	0	43	24.02
10	Baqui Medical University, Karachi	218	12	0	45	20.64
11	Mayo Hospital, Lahore	158	11	0	28	17.72
12	Ziauddin Medical University, Karachi	197	9	0	16	8.12
13	Nishtar Medical College & Hospital, Multan	169	7	0	7	4.14
14	Ayub Medical College, Abbottabad	172	8	0	5	2.91
15	Children's Hospital, Lahaore	139	11	0	18	12.95
16	Shifa International Hospital, Islamabad	137	10	0	11	8.03
17	Army Medical College, Rawalpindi	108	7	0	10	9.26
18	Fatima Jinnah Medical College, Lahore	100	9	1	15	15.00

TP=Total Papers; ICP=International Collaborative Papers; HCP=Highly Cited Papers

science and technology. These 15 authors together contributed 2311 papers with an average of 154.07 papers per author and account for 6.76% share in the cumulative publications output of Pakistan during 2001-10. Seven authors have published higher number of papers than the group average (154.07). These are: M. Ashraf with 275 papers, followed by Z.A. Bhutto (199 papers), S. Ali (194 papers), I.U. Khan (184 papers), M.N. Tahir (176 papers), K.M. Khan (173 papers) and M. Arshad (160 papers). Considering the citation/impact of papers, these productive authors have received a total of 11020 citations for these 2311 papers with an average of 4.77 citations per paper (varying from 1.84 to 15.03). Four authors have registered higher citation impact than the average impact of papers of all authors. These are Z.A. Bhutto with average citation per paper of 15.03, followed by A. Asghar (9.41), T.G. Kagi (7.87) and M.I. Bhanger (5.61). These 15 authors have received an average *h*-index of 15.60 (varying from 8 to 32). Seven authors have achieved the higher

h-index value than the group average of 15.60. These are Z.A. Bhutto with an *h*-index of 32, followed by S. Asghar (23), M. Ashraf (23), K.M. Khan (19), T.G. Kagi (19), M. Arshad (17) and M.I. Bhanger (16).

Preferred journals for publishing by Pakistani researchers

The top 20 most productive domestic journals publishing Pakistan's research papers in science and technology together contributed 10,180 papers, which accounts for 29.77% share in the cumulative publications output of Pakistan during 2001-10. The cumulative publications share of these 20 most productive domestic journals showed decrease in Pakistan's publications output from 40.43% during 2001-05 to 25.97% during 2006-10 (Table 14). Similarly, the top 20 most productive foreign journals publishing Pakistan's research papers in science and technology together contributed 2917 papers, which accounts for 8.53% share in the cumulative publications output of Pakistan during 2001-10. The cumulative publications share of these 20 most

Table 13—Productivity & impact of fifteen most productive Pakistani authors

Sl. no.	Authors	Affiliation	TP	TC	ACPP	<i>h</i> -index
1.	M. Ashraf	University of Agriculture, Faisalabad	275	1048	3.81	23
2.	Z.A. Bhutta	Aga Khan Univ., Deptt. of Pediatrics & Child Health, Karachi	199	2990	15.03	32
3.	S. Ali	Quaid-i-Azam Univ., Deptt. of Chemistry, Islamabad	194	576	2.97	14
4.	I.U. Khan	Govt. College Univ. Lahore, Deptt. of Chemistry, Lahore	184	391	2.13	9
5.	M.N. Tahir	Univ. of Sargodha, Deptt. of Physics, Sargodha	176	405	2.30	8
6.	K.M. Khan	Pakistan Institute of Nuclear Sc. & Technology, Islamabad	173	704	4.07	19
7.	M. Arshad	National Institute for Biotechnology & Genetic Engineering Pakistan, Faisalabad	160	707	4.42	17
8.	A. Saeed	Quaid-i-Azam Univ., Deptt. of Chemistry, Islamabad	135	249	1.84	8
9.	S. Asghar	Institute of Information Technology, Deptt. of Mathematics, Islamabad	129	1214	9.41	24
10.	A.R. Shakoori	Univ. of Lahore, School of Biological Sc. , Lahore	125	232	1.86	10
11.	T.G. Kagi	Univ. Of Sindh, National Centre for Excellence in Analytical Chemistry, Jamshoro	121	952	7.87	19
12.	A. Badshah	Quaid-i-Azam Univ., Deptt. of Chemistry, Islamabad	113	334	2.96	12
13.	W.H. Jafi	Aga Khan Univ. , Deptt. of Medicine, Karachi	112	385	3.44	13
14.	M.I. Bhanger	Univ. Of Sindh, National Centre for Excellence in Analytical Chemistry, Jamshoro	109	611	5.61	16
15.	V.U. Ahmad	Univ. of Karachi, H.E.J. Research Institute of Chemistry, Karachi	106	222	2.09	10
		Total	2311	11020	4.77	15.6
		Total of the country	34195			
		Share of 15 authors in country output	6.76			

TP=Total Papers; ACPP=Average Citation Per Paper; ICP=International Collaborative Papers

Table 14—Pakistan's top 20 most productive domestic journals

Sl. no	Journal	Number of papers		
		2001-05	2006-10	2001-10
1	<i>Journal of the College of Physicians & Surgeons Pakistan</i>	1122	1031	2153
2	<i>Pakistan Journal of Botany</i>	261	1290	1551
3	<i>Journal of Pakistan Medical Association</i>	645	838	1483
4	<i>Journal of Chemical Society of Pakistan</i>	275	612	887
5	<i>Medical Forum Monthly</i>	235	349	584
6	<i>Pakistan Journal of Zoology</i>	202	336	538
7	<i>Pakistan Journal of Medical Science</i>	207	275	482
8	<i>Journal of the Ayub Medical College Abbottabad</i>	126	345	471
9	<i>Pakistan Journal of Scientific & Industrial Research</i>	280	180	460
10	<i>Journal of the Association of Pakistan Dermatologists</i>	184	140	324
11	<i>Journal of the Liaquat University of Medical & Health Sciences</i>	0	182	182
12	<i>JPMI Journal of the Postgraduate Medical Institute</i>	0	148	148
13	<i>Pakistan Journal of the Pharmaceutical Science</i>	29	117	146
14	<i>Pakistan Pediatric Journal</i>	0	140	140
15	<i>Rawal Medical Journal</i>	0	135	135
16	<i>Natural Product Research</i>	46	85	131
17	<i>Pakistan Journal of Biological Science</i>	0	114	114
18	<i>Pakistan Journal of Nutrition</i>	9	99	108
19	<i>Pakistan Veterinary Journal</i>	0	74	74
20	<i>Pakistan Textile Journal</i>	10	59	69
	Total Papers	3631	6549	10180
	Country's Total Papers	8981	25214	34195
	Share of Top 20 Domestic Journals in Country Output	40.43	25.97	29.77

productive foreign journals showed decrease in Pakistan's publications output from 4.51% during 2001-05 to 9.96% during 2006-10 (Table 15).

Highly cited papers of Pakistan

Pakistan has published 63 highly-cited papers in science and technology in last 10 years (2001-10) and these have received between 101 and 615 citations per paper. Forty nine out of these 63 papers are a result of international collaboration (23 bilateral and 26 multilateral), 5 papers have authors collaborating within Pakistan and 9 papers do not have any collaboration.

Of the international collaborative papers, first authorship from Pakistan institutions was only in 8 and the remaining 41 papers had foreign institutions in first authorship. Of the 63 highly cited papers, 50 appeared as articles and 13 as review papers. In all, Pakistan participation in these 63 papers was confined to 34 institutions, which includes 12 papers each from Quaid-i-Azam University, Islamabad and Aga Khan University, Karachi, followed by National

Institute of Biotechnology & Genetic Engineering, Faisalabad (9 papers), University of Agriculture, Faisalabad (4 papers), 3 papers each from COMSATS Institute of Information Technology, Islamabad, University of Peshawar, Punjab University, Lahore and Pakistan Institute of Nuclear Science & Technology, Islamabad, 2 papers from NWFP Agricultural University, Peshawar and 1 paper each from 12 other Pakistan organizations. These 63 highly cited papers appeared in 43 journals, including 10 papers in *Lancet*, 3 papers in *Nature*, 2 papers each in *American Journal of Human Genetics*, *Cell*, *International Journal of Engineering Science*, *International Journal of Nonlinear Science & Numerical Simulation*, *Journal of Applied Microbiology*, *Journal of the American Chemical Society*, *Nature Genetics*, *Physics Letters, Section A* and *Virology* and 1 paper each in 32 other journals.

Conclusion

Pakistan has produced 34195 papers during the last ten years (2001-10), which is increasing at an annual

Table 15—Top 20 foreign journals publishing Pakistan's papers

Sl. no	Journal	Number of papers		
		2001-05	2006-10	2001-10
1	<i>Acta Crystallographica Section E. Structure Reports Online</i>	43	863	906
2	<i>African Journal of Biotechnology</i>	6	223	229
3	<i>International Journal of Agriculture & Biology</i>	0	200	200
4	<i>Physics of the Plasmas</i>	35	155	190
5	<i>Applied Mathematics & Computation</i>	11	129	140
6	<i>European Journal of Scientific Research</i>	0	131	131
7	<i>Journal of the Postgraduate Medical Institute</i>	63	58	121
8	<i>Journal of Enzyme Inhabitation & Medicinal Chemistry</i>	25	72	97
9	<i>Journal of Radioanalytical & Nuclear Chemistry</i>	50	47	97
10	<i>Journal of the Hazardous Materials</i>	3	93	96
11	<i>Lancet</i>	29	58	87
12	<i>Physics Letters, Section A.</i>	9	69	78
13	<i>Journal of Alloys & Compounds</i>	5	70	75
14	<i>Communications in Computer & Information Science</i>	0	75	75
15	<i>Turkish Journal of Chemistry</i>	31	43	74
16	<i>Radiochimica Acta</i>	26	41	67
17	<i>Chemical & Pharmaceutical Bulletin</i>	37	29	66
18	<i>Key Engineering Materials</i>	2	62	64
19	<i>Journal of Ethnopharmacology</i>	24	38	62
20	<i>Journal of Applied Physics</i>	6	56	62
	Total papers	405	2512	2917
	Country's total papers	8981	25214	34195
	Share of top 20 foreign journals in Country Output	4.51	9.96	8.53

average growth rate of 20.86%. Despite this growth rate, Pakistan needs to increase its output and bring about improvement in the quality of its research efforts. This can be done by investing much more in R&D, deploying more qualified manpower, increasing international collaboration and by modernizing and strengthening its existing research infrastructure.

References

- Shahid M, S&T indicators of Pakistan: A country report. 2010 South Asian Regional Workshop on STI Indicators, Kathmandu, Nepal, December 6-9, 2010. Available at: <http://www.uis.unesco.org/.../National%20STI%20Indicators%20Pak> (Accessed on December 3, 2011).
- Competitiveness Support Fund, The state of Pakistan's Competitiveness Report, 2010-11. <http://www.competitiveness.org.pk/downloads/SPCR2010.pdf> (Accessed on December 3, 2011)
- Higher Education Commission, Pakistan. Available at: <http://www.hec.gov.pk/Pages/UniversityBuilding.aspx> (Accessed on December 3, 2011)
- Laghari J R, Enter the unraveling, *Newsweek*, April 2011, Available at: <http://www.newsweekpakistan.com/the-take/297> (Accessed on December 3, 2011)
- Mahbuba D and Rousseau R, Scientific research in the Indian sub-continent: Selected trends and indicators 1973-2007 comparing Bangladesh, Pakistan and Sri Lanka with India, the local giant, *Scientometrics*, 84 (2) (2010) 403-420.
- Gupta B M, Munshi U M and Mishra P K, S&T collaboration of India with other South Asian countries, *Current Science*, 83 (10) (2002) 1201-09.
- Naim T K, Mapping scientific research in OIC countries, Available at: <http://portal.unesco.org/education/es/files/58030/12246005655Naim.pdf/Naim.pdf> (Accessed on December 3, 2011)
- Majid S, Trends in publishing agricultural research literature in Pakistan, *Science and Technology Libraries*, 15(3) (1996) 55-75.