

Comparative performance of India with other BRICS countries in publishing science and engineering research papers

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BRICS countries (Brazil, Russia, India, China and South Africa) together accounted for about 17.3% of total research papers in science and engineering published in 2011 compared to 7.6% in 1995, whereas their contribution to total doctorates produced in science and engineering in 2010 was 31.2% of the world total. India held second position in 1995 amongst BRICS countries and was behind Russia, whereas in 2011, China not only replaced Russia but also attained second position in publishing science and engineering research papers in the world, next only to USA.

Keywords: BRICS countries, R&D expenditure, research papers, science and engineering.

BRICS is an association of Brazil, Russia, India, China and South Africa, which represent the developing and newly emerging industrialized countries, except Russia. At present, BRICS countries represent approximately 3 billion people¹, which is around 42% of world's total population of about 7.074 billion (ref. 2), and hold about 27.3% of combined GDP (PPP) of the world³, with China on top (US\$ 12,269 billion) followed by India (US\$ 4793 billion), Russia (US\$ 3373 billion), Brazil (US\$ 2365 billion) and South Africa (US\$ 586 billion)³.

India's R&D investment was less than 2.5% of the world's US\$ 1.2 trillion in 2009 and is under 1.0% of its own GDP⁴. Increasing gross expenditure in research and development (GERD) to 2% of the GDP has been a national goal for some time⁴ along with the increase of share by private sector in R&D.

India held second position in terms of science and engineering research papers in 1995 and was placed below Russia, whereas in 2011 it surpassed Russia but lagged behind China. BRICS countries have attained a significant growth of 233.4% in publishing science and engineering research papers in 2011 over 1995 compared to 31.3% attained by rest of the world. BRICS accounted for 17.3% share of the world's research papers in science and engineering in 2011 compared to 7.6% in 1995.

The share of BRICS in producing doctorates in science and engineering accounts for 31.2% of the world. The number of research papers published is proportional to the number of researchers⁵, whereas the gross expenditure on R&D is directly proportional to the number of

research papers published⁶. An attempt has been made to compare the scientific outputs in terms of subject-wise research articles published in science and engineering by researchers from BRICS countries.

Methodology

Data pertaining to research publications and doctorates in science and engineering have been obtained from the reports on Science and Engineering Indicators – 2012 and 2014 by the National Science Foundation (NSF), USA and UGC Annual Report 2011–12. The data thus obtained have been analysed with respect to various parameters.

Scientific manpower and R&D spending vis-à-vis research papers published

Amongst the BRICS countries, Russia has maximum (3191) researchers per million inhabitants followed by China (1071), Brazil (694), South Africa (393) and India (137)⁷. Maximum absolute number of researchers was in China, followed by Russia, India, Brazil and South Africa. China's spending on R&D was highest amongst BRICS countries followed by India, Russia, Brazil and South Africa. China spent 1.97% of its GDP on R&D compared to 1.0% by Russia, 0.9% each by India and Brazil and 0.7% by South Africa⁸. It is noteworthy that out of the five BRICS countries, four, namely China, India, Russia and Brazil were amongst the top 20 leading countries in publishing science and engineering research papers⁶. In 1995, BRICS countries published only 7.6% of total research papers published in the world⁹ and their share increased to 17.3% in 2011 (ref. 10).

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Table 1. Subject-wise status of research papers published by BRICS countries in 1995 and 2011

Subject area	Brazil		Russia		India		China		South Africa		Total BRICS		World	
	1995	2011	1995	2011	1995	2011	1995	2011	1995	2011	1995	2011	1995	2011
Agricultural science	47	608	132	18	203	523	53	1,879	50	112	485	3,140	11,437	19,127
Astronomy	54	125	361	367	104	298	91	569	87	47	697	1,406	6,706	10,561
Biological science	1,038	3,560	3,356	939	1,875	3,843	902	13,507	698	881	7,869	22,730	146,293	171,720
Chemical science	378	1,622	4,421	4,227	2,472	6,178	2,014	22,342	230	354	9,515	34,723	68,319	115,188
Computer science	9	84	11	21	76	165	74	1,492	4	13	174	1,775	3,967	9,266
Engineering	220	1,084	1,552	1,065	1,170	3,778	1,273	15,209	118	291	4,333	21,427	42,103	88,773
Geoscience	164	758	719	943	385	1,052	306	4,298	255	288	1,829	7,339	27,659	46,218
Mathematical science	82	266	323	468	90	246	295	2,365	29	48	819	3,393	9,341	18,023
Medical science	587	3,265	701	527	930	2,132	853	9,526	546	541	3,617	15,991	135,648	182,772
Physical science	780	1,461	6,627	5,219	1,852	4,014	2,987	17,474	131	232	12,377	28,400	80,282	108,551
Psychology	20	106	125	128	22	43	64	385	66	85	297	747	13,554	23,231
Social science	59	207	277	228	191	207	150	846	140	232	817	1,720	19,335	34,275
Total	3,438	13,146	18,605	14,150	9,370	22,479	9,062	89,892	2,354	3,124	42,829	142,791	564,644	827,705

Source: www.nsf.gov/statistics/seind12 and www.nsf.gov/statistics/seind14

Table 2. Subject-wise relative percentage share of BRICS countries in publishing science and engineering research papers

Subject area	Percentage share of BRICS countries in 1995						Percentage share of BRICS countries in 2011					
	Brazil	Russia	India	China	South Africa	BRICS share	Brazil	Russia	India	China	South Africa	BRICS share
						(%) of the world total						(%) of the world total
Agricultural science	9.7	27.2	41.9	10.9	10.3	4.2	19.4	0.6	16.7	59.8	3.6	16.4
Astronomy	7.7	51.8	14.9	13.1	12.5	10.4	8.9	26.1	21.2	40.5	3.3	13.3
Biological science	13.2	42.6	23.8	11.5	8.9	5.4	15.7	4.1	16.9	59.4	3.9	13.2
Chemical science	4.0	46.5	26.0	21.2	2.4	13.9	4.7	12.2	17.8	64.3	1.0	30.1
Computer science	5.2	6.3	43.7	42.5	2.3	4.4	4.7	1.2	9.3	84.1	0.7	19.2
Engineering	5.1	35.8	27.0	29.4	2.7	10.3	5.1	5.0	17.6	71.0	1.4	24.1
Geoscience	9.0	39.3	21.0	16.7	13.9	6.6	10.3	12.8	14.3	58.6	3.9	15.9
Mathematical science	10.0	39.4	11.0	36.0	3.5	8.8	7.8	13.8	7.3	69.7	1.4	18.8
Medical science	16.2	19.4	25.7	23.6	15.1	2.7	20.4	3.3	13.3	59.6	3.4	8.7
Physical science	6.3	53.5	15.0	24.1	1.1	15.4	5.1	18.4	14.1	61.5	0.8	26.2
Psychology	6.7	42.1	7.4	21.5	22.2	2.2	14.2	17.1	5.8	51.5	11.4	3.2
Social science	7.2	33.9	23.4	18.4	17.1	4.2	12.0	13.3	12.0	49.2	13.5	5.0

Subject-wise performance in comparison to India

In 1995, China was ahead to India only in the area of engineering, mathematical science, physical science and psychology, whereas Russia was ahead to India in all subjects, except agricultural science, computer science and medical science. South Africa was ahead only in psychology, whereas Brazil was not ahead in any subject area (Table 1). In 2011, analysis revealed that China surpassed both India and Russia in all subject areas, whereas India emerged ahead of Russia in the area of agricultural science, biological science, chemical science, computer science, engineering, geoscience and medical science and attained second rank amongst the BRICS countries. Russia, who was the leader in 1995 in publishing science and engineering research papers amongst the BRICS countries, could maintain its lead over India only in astronomy, mathematical science, physical science, psychology

and social science in 2011. Further, Brazil surpassed India in the area of medical science and psychology, whereas South Africa was ahead of India only in psychology and social science (Table 1). Though India has made a significant growth in publishing science and engineering papers in the year 2011 over 1995 in all subject areas, her share of research publications amongst BRICS countries, except for astronomy, decreased. It decreased in agricultural science from 41.9% in 1995 to 16.7% in 2011; biological science from 23.8% to 16.9%; chemical science from 26% to 17.8%; computer science from 43.7% to 9.3%; engineering from 27% to 17.6%; geoscience from 21% to 14.3%; mathematical science from 11% to 7.3%; medical science from 25.7% to 13.3%; physical science from 15% to 14.1%; psychology from 7.4% to 5.8% and social science from 23.4% to 12% (Table 2). The drastic drop in India's share in research publications is due to the phenomenal increase in research papers published by China in the year 2011 over 1995.

Table 3. Subject-wise percentage change in 2011 over 1995 in publishing science and engineering research papers by BRICS countries

Subject area	Percentage change in the number of research papers in 2011 over 1995 of BRICS countries						Percentage change in 2011 over 1995 in countries other than BRICS
	Brazil	Russia	India	China	South Africa	BRICS (together)	
Agricultural science	1193.6	-86.4	157.6	3445.3	124.0	547.4	46.0
Astronomy	131.5	1.7	186.5	525.3	-46.0	101.7	52.4
Biological science	243.0	-72.0	105.0	1397.5	26.2	188.9	7.6
Chemical science	329.1	-4.4	149.9	1009.3	53.9	264.9	36.8
Computer science	833.3	90.9	117.1	1916.2	225.0	920.1	97.5
Engineering	392.7	-31.4	222.9	1094.7	146.6	394.5	78.3
Geoscience	362.2	31.2	173.2	1304.6	12.9	301.3	50.5
Mathematical science	224.4	44.9	173.3	701.7	65.5	314.3	71.7
Medical science	456.2	-24.8	129.2	1016.8	-0.9	342.1	26.3
Physical science	87.3	-21.2	116.7	485.0	77.1	129.5	18.0
Psychology	430.0	2.4	95.5	501.6	28.8	151.5	69.6
Social science	250.8	-17.7	8.4	464.0	65.7	110.5	75.8
Overall	282.4	-23.9	139.9	892.0	32.7	233.4	31.3

Subject-wise growth in publishing science and engineering research papers

BRICS countries showed a significant growth of 233.4% in publishing research papers in the year 2011 over 1995 (Table 3). The BRICS countries' share of research papers increased from 4.2% in 1995 to 16.4% in 2011 in the area of agricultural science; 10.4% to 13.3% in astronomy; 5.4% to 13.2% in biological science; 13.9% to 30.1% in chemical science; 4.4% to 19.2% in computer science; 10.3% to 24.1% in engineering; 6.6% to 15.9% in geoscience; 8.8% to 18.8% in mathematical science; 2.7% to 8.7% in medical science; 15.4% to 26.2% in physical science; 2.2% to 3.2% in psychology, and 4.2% to 5.0% in social science (Table 2). Subject-wise growth of BRICS countries in publishing science and engineering research papers in 2011 over 1995, indicates that maximum growth rate was in the area of computer science (920.1%), followed by agricultural science (547.4%), engineering (394.5%), medical science (342.1%), mathematical science (314.3%), geoscience (301.3%), chemical science (264.9%), biological science (188.9%), psychology (151.5%), social science (110.5%) and astronomy (101.7%) (Table 3).

For countries other than BRICS, the growth in publishing science and engineering research papers in the year 2011 over 1995 was much lower than the BRICS countries. Maximum growth in the case of countries other than BRICS was seen in computer science (97.5%) followed by engineering (78.3%), social science (75.8%), mathematical science (71.7%), psychology (69.6%), astronomy (52.4%), geoscience (50.5%), agricultural science (46.0%), chemical science (36.8%), medical science (26.3%), physical science (18%) and biological science (7.6%; Table 3). Further, the analysis showed that India's growth, except in social science was higher in all other subject areas than that attained by countries other than BRICS in the year 2011 over 1995 (Table 3).

China's maximum growth in research papers published in 2011 over 1995 has been observed in the area of agri-

cultural science (3445.3%) and the minimum growth in the area of social science (464%). India achieved maximum growth in the area of engineering (222.9%) followed by astronomy (186.5%), mathematical science (173.3%), geoscience (173.2%), agricultural science (157.6%), chemical science (149.9%), medical science (129.2%), computer science (117.1%), physical science (116.7%), biological science (105%), psychology (95.5%), and minimum (8.4%) in the area of social science (Table 3). Amongst other BRICS countries, Brazil achieved maximum growth (1193.6%) in the area of agricultural science, whereas Russia and South Africa achieved maximum growth of 90.9% and 225% respectively, in the area of computer science. Amongst the BRICS countries, Russia's growth nose-dived to the negative side in all subject areas, except astronomy (1.7%), psychology (2.4%), geoscience (31.2%), mathematical science (44.9%), and computer science (90.9%; Table 3).

Subject-wise performance in producing doctorate degrees

Data pertaining to subject-wise doctorate degrees awarded by BRICS countries in 2010 indicate that China was the leading country in producing Ph D doctorates in science and engineering followed by Russia, India, Brazil and South Africa (Table 4). It is important to note that BRICS countries contributed to 31.2% of total doctoral degrees awarded in science and engineering in the world. The share of BRICS countries was highest (39.5%) in the area of engineering followed by agricultural science (38.2%), physical/biological science (31%), social/behavioural science (25.4%) and 2.2% in mathematical/computer science (Table 4). India's share in doctorates degree awarded by BRICS countries in the area of physical/biological science was 24.1%, compared to 45% of China, 20% of Russia, 9.9% of Brazil and 1% of South Africa. In agricultural science, India's share was

Table 4. Subject-wise number of doctorates awarded in 2010 by BRICS countries in science and engineering

Country	Physical/ Biological science	Mathematical/ computer science	Agricultural science	Social/ behavioural science	Engineering	Total
Brazil ^a	2,122	248	1,081	798	1,221	5,470
Russia ^a	4,296	–	796	6,017	4,605	15,714
India ^b	5,005	–	814	–	1,449	7,268
China ^a	9,638	–	1,973	2,371	17,428	31,410
South Africa ^c	206	40	54	151	108	559
Total	20,444	288	4,988	10,080	21,565	60,421
World ^a	69,225	13,114	11,928	36,757	62,813	193,837
% of BRICS to that of the world	31.0	2.2	38.2	25.4	39.5	31.2
India's share to that of BRICS	24.1	–	14.3	–	5.8	12.0

Source: ^awww.nsf.gov/statistics/seind14; ^bAnnual Report, UGC, New Delhi; ^cwww.nsf.gov/statistics/seind12; –, Not given.

14.3% compared to 43.3% of China, 23.7% of Brazil, 17.5% of Russia and 1.2% of South Africa. In engineering, India's share was just 5.8% in comparison to 70.2% of China, 18.6% of Russia, 4.9% of Brazil and 0.4% of South Africa (Table 4). Analysis revealed that India is far behind China in producing doctorates in engineering, unlike other subject areas.

Science and engineering research papers output and its relation to GERD

China achieved a growth of 892% in the year 2011 over 1995 compared to 282.4% of Brazil, 139.9% of India, 32.7% of South Africa and –23.9% of Russia (Table 3) in publishing science and engineering research papers. China's growth may be attributed to its significant increase in expenditure on R&D. Gross expenditure on R&D by China in 1995 was only US\$ 11.7 billion, which increased to US\$ 154.1 billion (ref. 9) in 2009, and according to recent report it reached to US\$ 296.8 billion in 2012 (ref. 8). India on the other hand has spent only US\$ 36.1 billion, followed by Russia (US\$ 23.8 billion), Brazil (US\$ 19.4 billion) and South Africa (US\$ 3.7 billion)⁸. Amongst the BRICS countries, India has been ranked second after China in 2009 in publishing science and engineering research and its expenditure on R&D was higher than Brazil, Russia and South Africa, but far below that of China. Thus, the expenditure on R&D has an impact on scientific output as is evident from China's phenomenal growth in publishing science and engineering research papers and achieving the second position after USA, which still spends the highest on R&D in the world.

Indian universities rankings amongst BRICS and emerging economies

Amongst the top 100 universities of BRICS and emerging economies in 2014, 44 universities were from BRICS, whereas the rest 56 were from other emerging economies

such as Taiwan (21), Turkey (7), Thailand (5), Poland (4), etc. Thus BRICS has a share of 44% amongst the top 100 universities in comparison to 56% by emerging economies other than BRICS. Amongst the BRICS countries, China was leading with 23 universities, followed by India (10), South Africa (5), Brazil (2) and Russia (2)¹¹.

Conclusion

A significant growth of 233.4% has been observed in the year 2011 over 1995 in publishing science and engineering research papers by all BRICS countries together in comparison to 31.3% growth achieved by countries other BRICS. Amongst BRICS countries, China had maximum researchers followed by Russia, India, Brazil and South Africa; however, the performance of Indian researchers per billion US\$ in publishing science and engineering research papers was better than all BRICS countries, including China⁶. Thus, with significant hike in its GERD and enhancement in its pool of scientific manpower, India will emerge as one of the leading countries in publishing science and engineering research papers.

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