



Scientific Research in India:

Drawing Insights from Bibliometric Indicators

ISTIP Policy Bulletin No. 3 January 2014

ISTIP (Indian S&T and Innovation Policy): First Study of its kind focusing on various dimensions of innovation activity in India; aiming at providing valuable inputs for S&T and Innovation decision making.

Contents

- The Changing Global Landscape of Science
- Indian Publication Trend and Forecast
- Indian Research Impact
- Final Remarks and Policy Implications

This Policy Bulletin has been prepared under ISTIP project by Sujit Bhattacharya (Principal Author), Shilpa, Arshia Kaul. Authors are affiliated to CSIR – NISTADS.

The Changing Global Landscape of Science

The global landscape of science is changing with new centers of research hotspots visible in emerging/newly industrialised economies. A strong evidence of this changing landscape is coming from ‘research publications’, an indicator commonly used as ‘proxy’ for measuring research activity (including performance/productivity). Publication output of scientifically advanced countries is increasing at a slower pace than in countries which were traditionally follower countries. This is more evident in emerging scientific fields in which unlike the earlier times many emerging economies are challenging the scientific dominance of advanced OECD countries. Scientifically proficient South countries (Brazil, China, and India, for example) are investing substantial resources in the newly emerging fields in which technologies are increasingly science-based.

These countries see this investment as a ‘Window of Opportunity’ for them to move up the Science-Technology-Innovation (STI) value chain and exploit that competency for developing commercially successful innovative products and /or processes.

New realities of global science in the 21st century can be seen, for example from the involvement of emerging countries in nanoscience and nanotechnology (substantial investment and capacity build up) leading to tangible outcomes. Nanotechnology is a highly interdisciplinary area where technology development is contingent upon scientific advance and promises solutions to complex technological problems. Thus intensity of research publications in this field by a country is a good indication of scientific capacity. China and to some extent India are now emerging among the top ranked countries publishing in this area.

Among the key questions that are drawing global attention is *'how the global landscape of science is changing the dynamics of scientific activity?; 'What are the factors that are playing a major role in changing the global scientific landscape?; 'What is happening in newly emerging areas such as nanotechnology in which scientific research has strong correlation with developing novel solutions to complex technological problems?; What types of scientific competency are visible in emerging economies?*

The bulletin examines some of the key questions/issues raised by scholars and policy makers of the changing contours of global science and emergence of new players (primarily the scientifically proficient South countries) and its implications. The examination is based on analysing peer reviewed research publications of India over a period of time. India to a large extent epitomises the scientific activity of emerging economies and thus many of the issues raised can be informed from this analysis. The analysis is primarily based on publications covered by the SCI-E. The study also draws from other bibliographic databases: the SCOPUS and the Journal Citation Report (JCR). To place Indian publication activity in proper context, her publication activity is compared with some scientifically proficient countries, i.e. with the other countries in the so called BRICKS (Brazil, Russia, India, China, South Korea, and South Africa) countries. The BRICKS countries publication activity in general and Indian activity in particular is also compared with some advanced OECD countries to have a more informed reflection of the global landscape of science.

Table 1 highlights China's strong investment in R&D. It also shows South Korea's priority for R&D. Huge outlay for R&D is surely one of the major drivers behind China and South Korea's emergence in the global STI landscape in recent years.

India and Comparator Countries: Key R&D Statistics

Table 1: R&D Investment Statistics of the Countries Examined in this Study (2012)

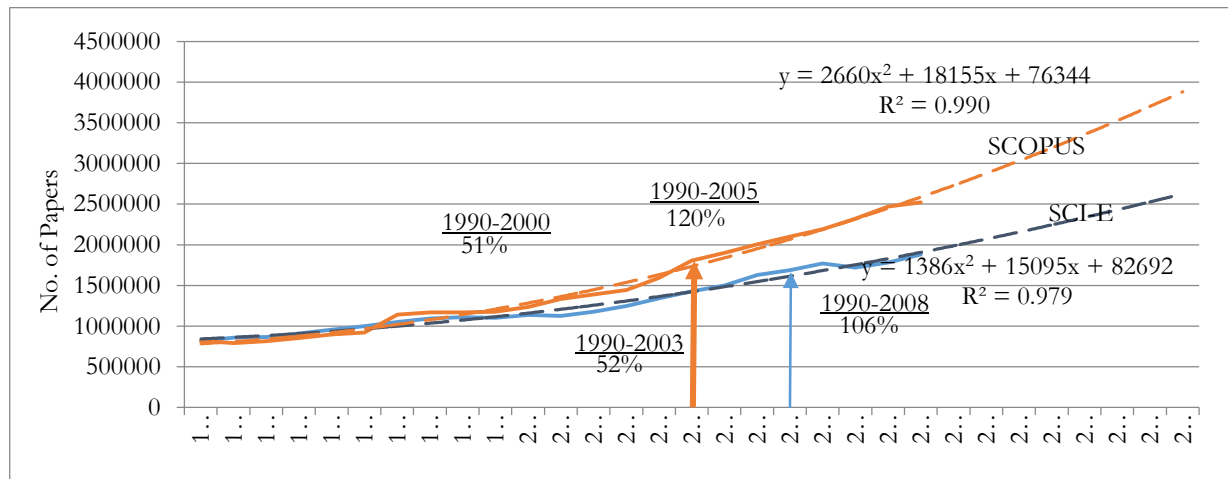
	Total GDP ¹	Total GERD ¹	% Share of World R&D ²	GERD as % of GDP	Researchers ²
USA	16244.6	452.6	29	2.8	14,25,550
Japan	4488.3	157.1	11.1	3.5	6,56,651
Germany	3377.5	104.4	6.1	3.1	2,90,853
France	2371.9	53.4	3.8	2.3	2,15,755
UK	2368.2	41.9	3.2	1.8	2,62,303
Russia	3373.2	36.4	2.5	1.1	4,47,579
South Korea	1540.2	53.1	4	3.5	2,88,901
China	12314.7	197.1	13.7	1.6	13,18,086
India	1841.7	14.8	2.8	0.8	1,54,827
South Africa	569.5	5.4	0.4	0.9	19,320
Brazil	2435.2	30.4	1.9	1.3	1,33,266

Source: NSF (2013), OECD Stat (2013), Eurostat (2012), and UNESCO report (2010); Note: ¹Figures of GDP (Gross Domestic Product) and GERD (Gross Domestic Expenditure on R&D) are in US Billion Dollars; ²2012 or latest data available.

Global Publication Trend and Forecast

The global publication is increasing at a very fast rate showing exponential growth pattern (Figure 1).

Figure 1: Publication Trend and Forecast of Global Research Output (1990-2020)



Note: SCI-E and Scopus are two major bibliographic databases covering papers from peer reviewed journals in different disciplines. Last few years they have started covering major conference proceedings and influential books.

The global publication pattern shows transition from steady growth to exponential behaviour in the year 2000 (Scopus), and 2003 (SCI-E). One characteristic of the exponential behaviour is the doubling time i.e. the time it takes publications from a particular year to double. The doubling time for publications covered by the Scopus and the SCI-E, taking 1990 as the base year, is 15 years and 18 years respectively. Publication increased by 50% in 2000 from that in 1990 covered by the Scopus whereas it took only 5 years to increase output by further 50%. In the SCI-E database it took somewhat more time i.e. 13 years to increase output by 50% from that in 1990. However, from 2003 onwards, it took only 5 years to increase output by 50% (Figure 1). Publications covered by these two databases maintain their exponential curve in the current period. The publications covered by the SCI-E for example increased by 9% in 2012 from that in 2010. In the Scopus during the same period the publication increased by 8.5%. Forecasting for the later periods shows the curve is maintaining exponential growth. The predicted publications covered by the SCI-E in 2015 is 21,56,333 (15% increase from 2012) and in

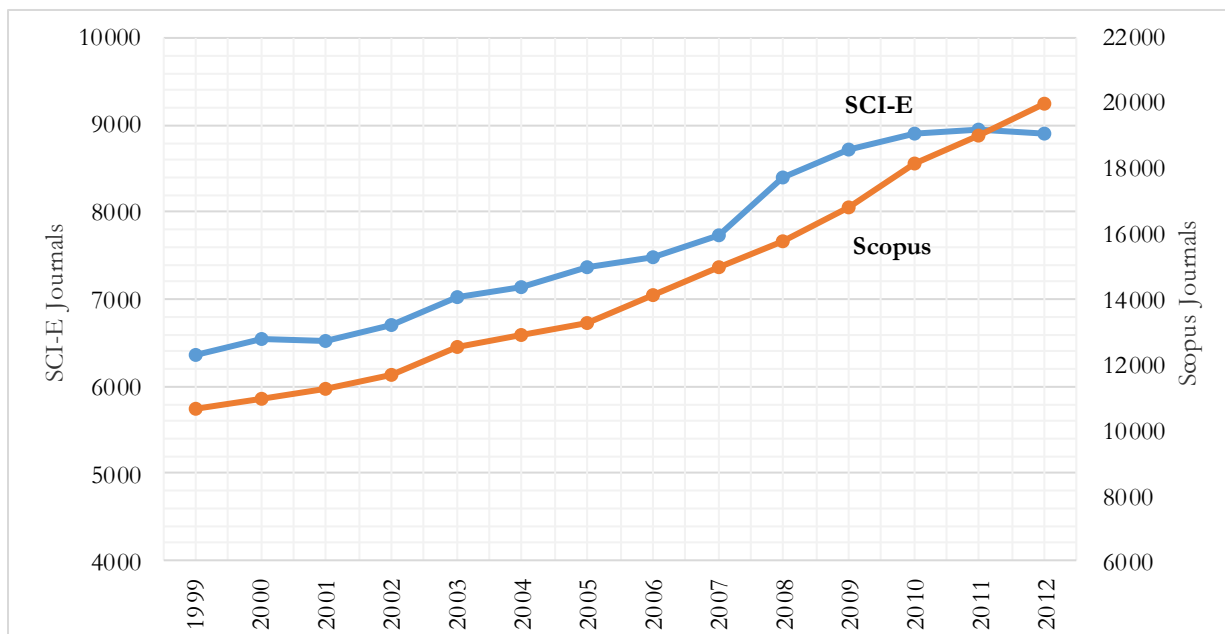
2020, 26,26,818 (40% increase from 2012). The predicted publications covered by the Scopus in 2015 is 30,33,636 (20% increase from 2012) and in 2020 is 38,82,511 (54% increase from 2012). The difference in growth behaviour discerned from publication activity in the two databases may be emerging due to the scope of the databases; Scopus has a much larger coverage than SCI-E.

The findings are intertesting and striking as it exhibits that scientific research is moving at a much faster pace then imagined!

What has contributed to the global publication growth?

Expansion of Journal Coverage in Major Bibliographic Databases: The SCI-E is part of WoS (Web-of Science) and covers around 8,000 or so journals mainly in science, technology and engineering. The Scopus on the other hand covers 17,000 journals in natural and social sciences including humanities. Figure 2 exhibits the journals indexed by the SCI-E from 1990 to 2012.

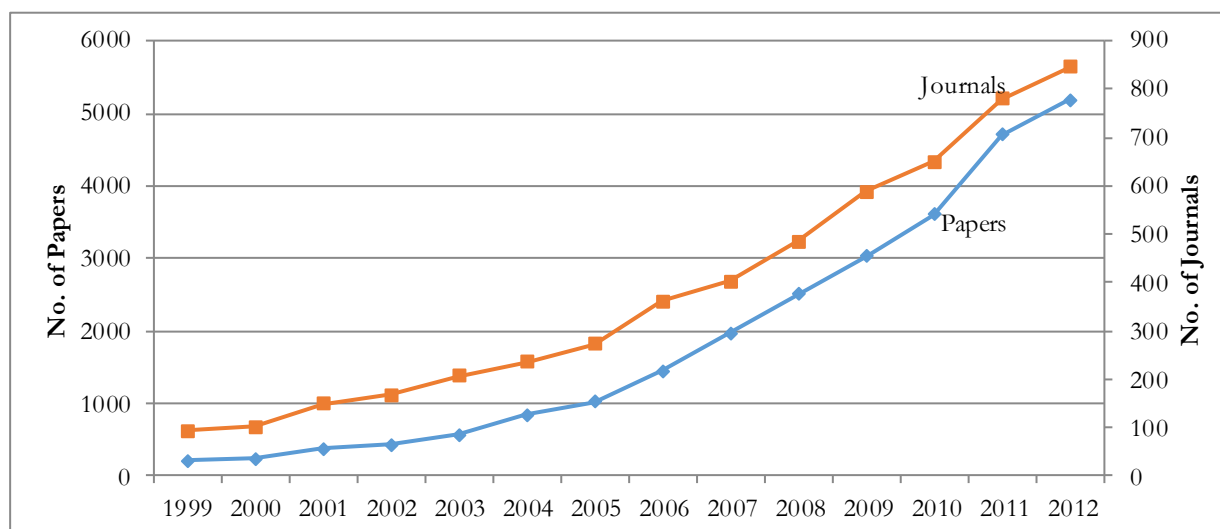
Figure 2: Journal Coverage in the SCI-E and the Scopus (1999-2012)



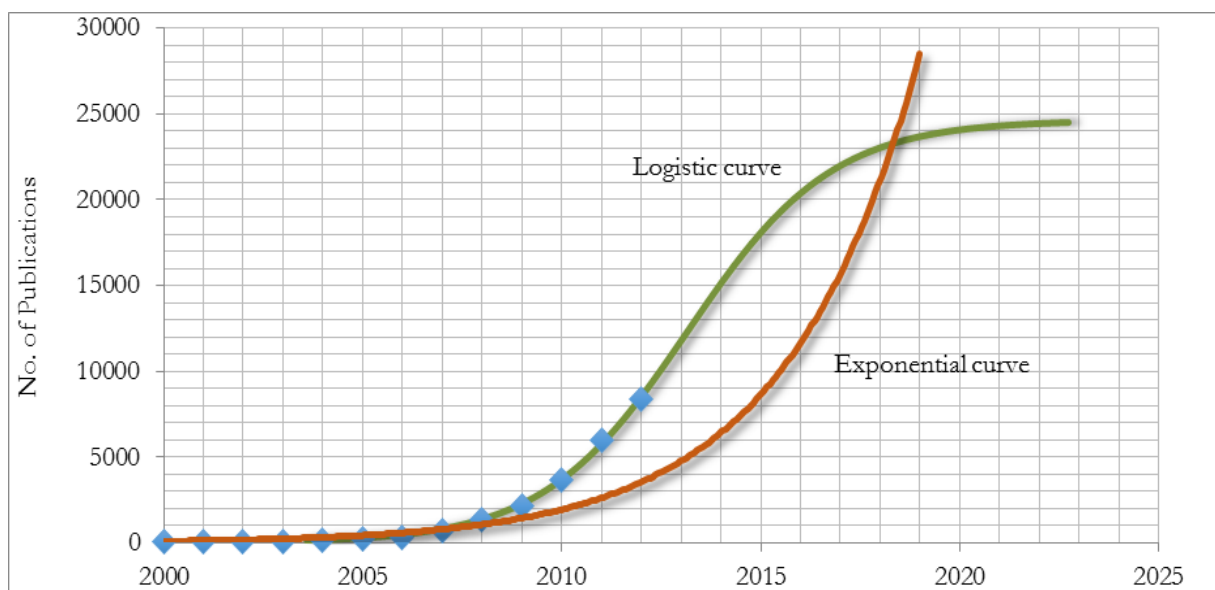
The significant rise in the coverage of journals in the SCI-E and Scopus can be observed in above figure. In 2000, the number was 6,535 journals in SCI-E and 10,953 in Scopus. The coverage of journals in SCI-E increased by 45% in year 2000 and roughly doubled in

the year 2012 taking base year as 1990. Study has shown that expansion of journals in the SCI-E is due to larger coverage of journals from emerging economies (a case in point is India as shown later), emergence of new research areas and in those new journals getting published (shown through the example of nanotechnology later), and many journals which were not indexed earlier now part of the SCI-E database. Thus one can clearly see that increase in coverage of journals by the SCI-E provides opportunity for researchers to expand their journal set for publishing papers in the SCI-E databases. *Thus global growth of publications has strong correspondence with increase in journals covered by the SCI-E.* This similar phenomenon is visible in the SCOPUS database.

Emergence of New Research Areas: Price (1963) has shown by observing research publication trends over a long period of time in different research fields that the trends are similar to logistic curve i.e. S-shaped ogive (exponential growth with saturation). New logistics are born (escalation) from the earlier logistic growth curve. The shape of the global publication distribution from 1990 can be similarly discerned. New emerging areas like nanotechnology play an influential role in changing the shape of the distribution from linear to exponential growth. The emergence of research community in a new field and new journals in that field provides the impetus for exponential growth in an emerging area (Figure 3). Figure 4 highlights how even within the fast growing fields that exhibit exponential growth (such as nanotechnology) there are subfields that are in the beginning of the exponential curve during the current period and show further steep growth leading to logistic curve. Geim and Novoselov's discovery of graphene in 2004, the Nobel prize award to the duo in year 2010 and the simple technique for making graphene that they demonstrated are possibly behind this growth. The curve would take a logistic shape in the future because of Graphene research getting more applied as already observed in high-speed electronics and in flexible circuitry.

Figure 3: Nanotechnology: Global Publication and Journal Trend

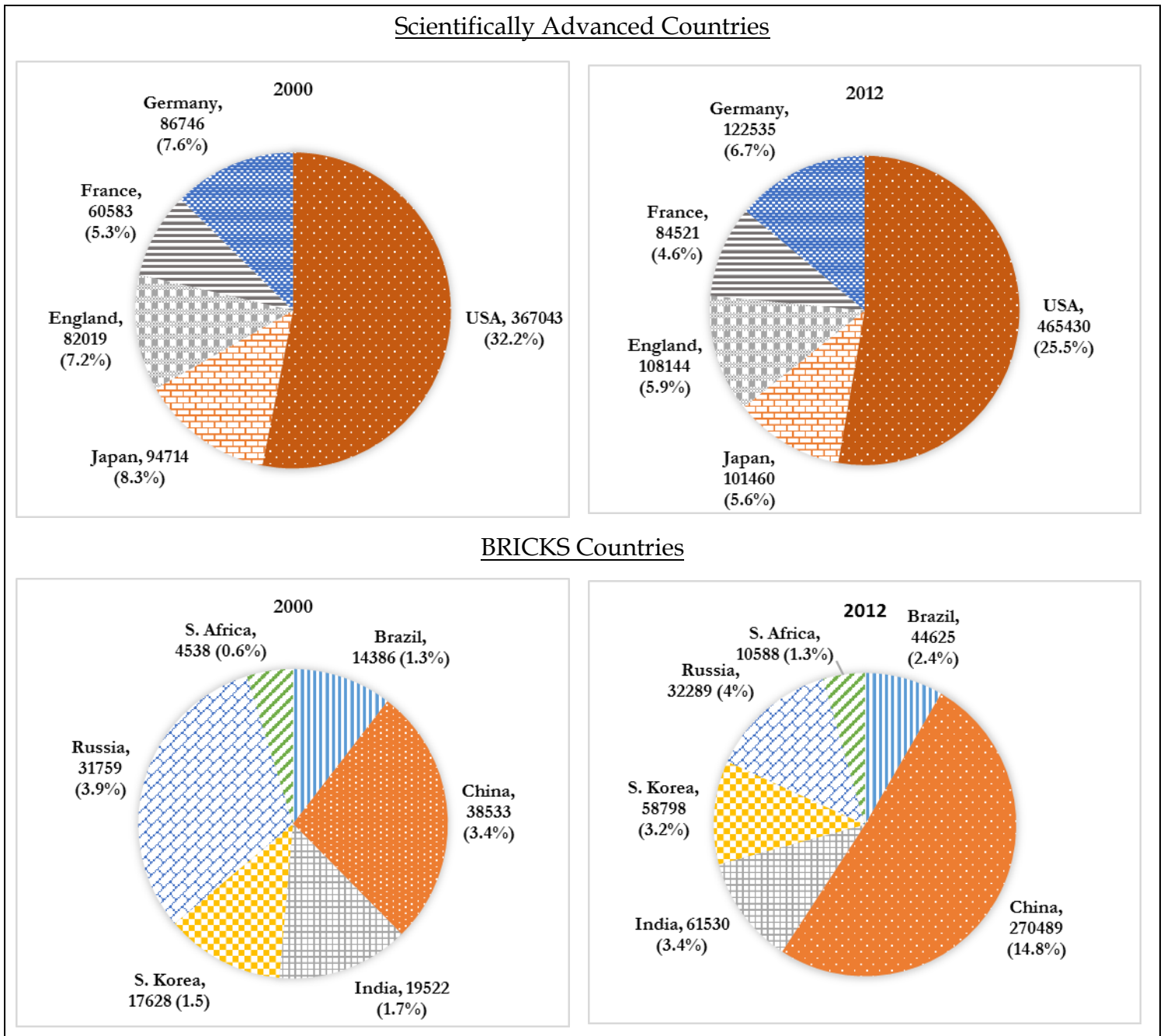
Source: SCI-E

Figure 4: Growth Forecast of Global Publication in Graphene

Source: Scopus

Increasing Scientific Activity of Emerging Economies: Another major cause behind the global publication growth can be seen from the increasing scientific activity of emerging economies. Figure 5 provides evidence for this statement.

Figure 5: Publication Statistics of BRICKS and Some Advanced OECD Countries



Source: SCI-E; Note: BRICKS => Brazil, Russia, India, China, S. Korea and S. Africa; the Figure includes the number of papers and the percentage share of global papers of a country (enclosed in bracket).

Figure 5 also provides insight of how the global publication landscape is changing. One can see the emergence of BRICKS countries with China emerging as the leading publishing country globally after USA in 2012. In 1990s the BRICKS countries were insignificant players with less than 1% of share by each of these countries. In 2006, South Korea and India increased their share above 2%. It is only Russia, a dominant country (in terms of publication output) among BRICKS which has not been able to increase share in publications in recent years.

In newly emerging areas the change in global landscape is more strongly visible. In nanotechnology, for example, China became a leader in 2011 leaving behind the developed countries in the nanotechnology publication race¹. India improved her rank from 13th in 2000 to 6th in 2011.

International Collaboration: The scientific world is becoming increasingly interconnected, with international collaboration on the rise. As Wagner (2008)² puts it, new invisible colleges of science are continuously developing and new global networks which form an open system of learning are emerging through cooperation and various forms of collaborations. International collaborations examined through scientific papers show over 35% of articles published in international journals are internationally collaborative, up from 25% from that of 15 years ago³.

Countries have increased their collaboration rate over the years⁴. USA doubled its collaborative papers with China, UK and Germany from 2003 to 2011. This has also contributed to increased US total output. China's rapid growth since 2000 is leading to closer research collaboration with Japan (up fourfold since 1999), Taiwan (up eightfold), South Korea (up tenfold), Australia (more than tenfold) and with every other research-

¹Bhattacharya, S., Shilpa and Bhati, M. (2012). China and India: The two new players in the nanotechnology race. *Scientometrics*, Vol. 93 (1), pp. 59-87.

²Wagner, C. (2008). The New Invisible College: Science for Development. Washington DC: Brookings Institution Press.

³Royal Society (2011). Knowledge, Network and Nations. UK: Royal Society Publishing.

⁴Adams, J. (2012). Collaborations: The rise of research networks. *Nature*, Vol. 490, pp. 335-336. doi:10.1038/490335a

active country in the Asia-Pacific region. India is also expanding her research network particularly the increase observed in joint collaborative papers with countries in Asia i.e. Japan, South Korea, Taiwan and China.

Which Countries are Showing Maximum Productive Efficiency?

Publication intensity as percentage of GERD is a crude measure of 'return to investment'. Nevertheless, it does provide some indication of productive efficiency.

Figure 6: Publication Intensity as Percentage of GERD



Source: OECD, Stat, Eurostat, and UNESCO report; Note: GERD in US million Dollars

India shows high return to investment implying that India spends the least amount among the comparator set of countries for paper production.

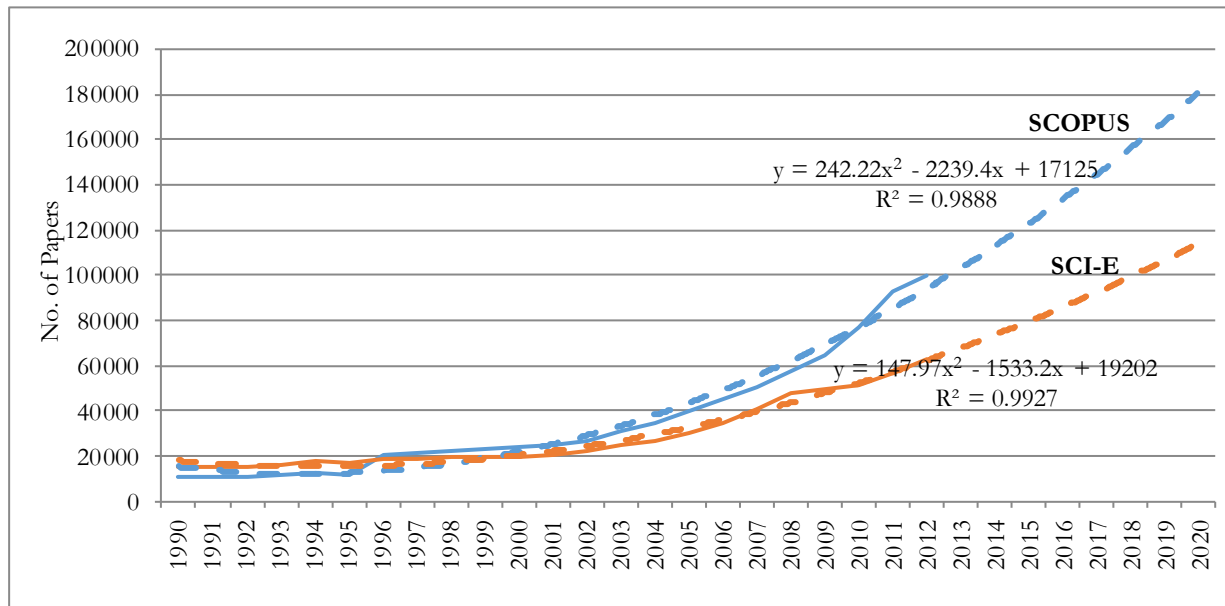
Indian Publication Trend and Forecast

India in 2012 became the 7th most active publishing country in journals covered by the Scopus and 10th in the SCI-E. The publication trend in both these databases are shown in Figure 7.

It can be observed from year 2000 the publication curve starts changing from linear growth to an exponential growth pattern. Taking 2000 as the transition year, the publications covered by both the databases have more than doubled in 2012; 221% increase in the SCI-E and 321% increase in the Scopus. Forecasting shows the slope of

the curve increasing more steeply (exponentially) from 2012 implying taking less time for publications to cumulate. As per the forecasting model, the publications in 2020 in the SCI-E will be 1,13,872 papers (82% increase from 2012) and in the Scopus 1,80,480 papers (81% increase from 2012).

Figure 7: Indian Publication Trend and Forecast (1990-2020)

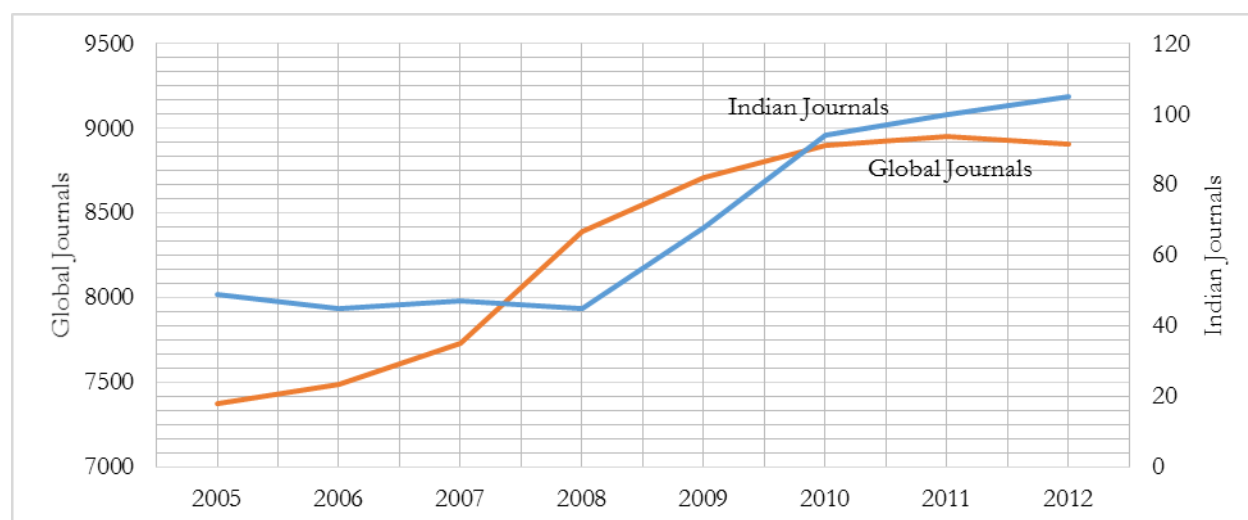


What is Behind Publication Growth of India?

Four major reasons behind the exponential nature of growth of Indian papers from 2000 were discerned: (a) *Expansion of journals and Inclusion of Indian journals*, (b) *Increase in Institution involved in publishing activity* (c) *Increase in international collaboration*, (d) *Activity in emerging research areas*.

a) Expansion of Journals in Global Databases and Inclusion of Indian Journals

The SCI-E and the Scopus are increasing their journal coverage every year (Figure 8). In the SCI-E for example, the number of journals almost doubled in 2012 (8,903 journals indexed) from that in 1987 (4,472 journals indexed).

Figure 8: Global and Indian Journals in the SCI-E

Source: SCI-E, which is increasing year-on-year.

The increase in journals in these two databases provides more opportunity for Indian researchers to publish in journals covered by them. Generally papers published in a journal show tendency of 'home advantage'. This is clearly seen in the case of Indian journals with a large number of papers in these journals coming from Indian researchers.

The SCI covered 36 Indian journals in 1980 which declined to 10 journals in 1997. This had a major effect on Indian publishing activity as it was shown that the mean number of papers originating from India in an Indian journal in SCI is more than 100 per year as compared to only 5 such papers on average in any other SCI journal in which Indian papers appear⁵. The reduction in journal coverage has marked effect on Indian SCI publication can be observed. The SCI-E again started indexing a number of Indian journals, increase observed year-on-year (Figure 8). On an average it has been observed that more than 50% of the papers in these journals have papers from Indian authors. Thus inclusion of Indian Journals in SCI-E has major effect on India's publication trend. Table 2 provides further insight of the effect of expansion of journals and inclusion of Indian journals in the SCI-E.

⁵ Basu, A. Are Indian Scientists Losing in the World Publishing Race? – A Refutation. In: *Emerging Trends in Scientometrics*. (1999), Edited by P.S. Nagpaul, K.C. Garg, B.M. Gupta, S. Bhattacharya and A. Basu. New Delhi: Allied Publishers limited.

Table 2: Publications and Journals from Indian Institutions

Year	Global Papers	Total Journals in the SCI-E	Total Indian Papers	Total Journals in which India is publishing	Indian Journals covered in SCI-E
2005	12,39,586	7,378	27,726	3,630	47
2008	14,09,798	8,393	42,508	4,462	44
2012	18,77,797	8,903	61,530	5,227	105

Source: SCI-E and JCR

This is also one of the major factors behind the publication growth of Indian research papers in the Scopus. Scopus has been increasing journal coverage over the years; for example in 1999, 10,623 journals were indexed by this database whereas in 2012 this increased to 19,988 journals. The number of Indian journals covered by this database has also substantially increased over the years with 130 Indian journals covered in 1999 and 362 in 2012.

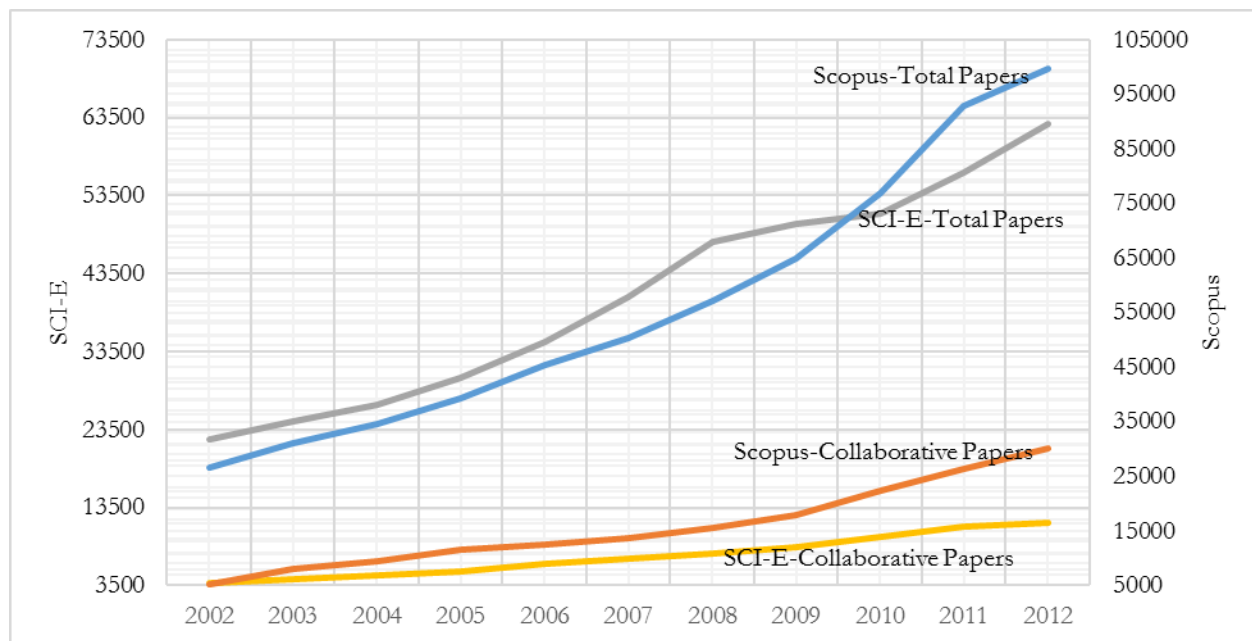
b) Expansion of Institutes Involved in Publishing Activity

The number of institutes involved in publishing activity has increased over the period. This has also major implications for the increase in growth. There were 8,147 institutions involved in publishing activity in 2006 which increased to 18,889 in 2012.

c) Increase in International Collaboration

International collaboration is a recent phenomenon of India's scientific research; it was of lesser significance as far as its numbers were concerned relative to the overall number. The exponential model of growth obtained through trend analysis of collaborative scientific publications completely discounts the involvement of internal scientific publications. Scaling relationships, however, overcome this limitation⁶. The predicted value of internationally collaborative scientific publications based on scaling relationship in the SCI-E is 23,968 in 2015 and 44,143 in 2020. Based on similar approach, the internationally collaborative papers in the Scopus are predicted as 50,046 and 96,215 for 2015 and 2020 respectively.

⁶ Shrivats, S. V. and Bhattacharya, S. (2014). Forecasting the Trend of International Scientific Collaboration. *Scientometrics*. Forthcoming

Figure 9: Trend of Internationally Collaborative Papers from India

d) Activity in Emerging Research Areas

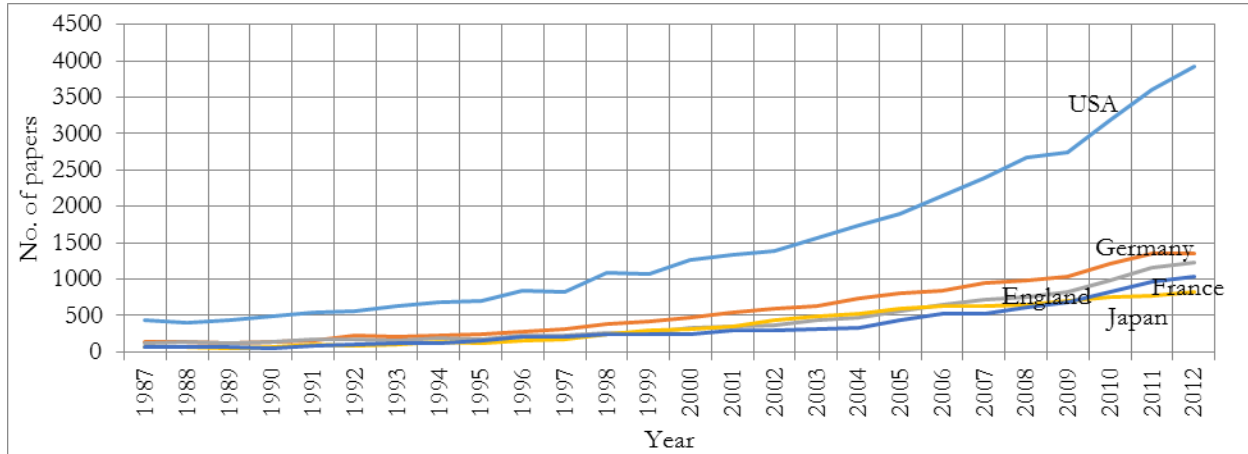
In the overall expansion of the SCI-E journal set there is a strong influence of journals from emerging fields/subfields, for example, nanotechnology, advanced materials, computational biology. Indian researchers are actively using these journals for publishing. This has placed India among the top 15 countries in many of these fields/subfields. This has also a marked effect on India's publication growth.

How India is Collaborating with Other Countries?

The major collaborating partners of India can be seen from Figure 10. The top five countries contribute roughly 82% of collaborative papers in 2000, and 72% of collaborative papers in 2012. USA is a major collaborating partner with around 34% contribution to India's collaborative papers. The internationally collaborative papers have shown conspicuous absence of Indian researcher's engagement with developing countries, countries in Asia and the BRICKS countries particularly in the period before

2010. This is a stark difference from the behavior of scientifically advanced and other emerging countries⁷. India's collaborating pattern however is changing in recent years.

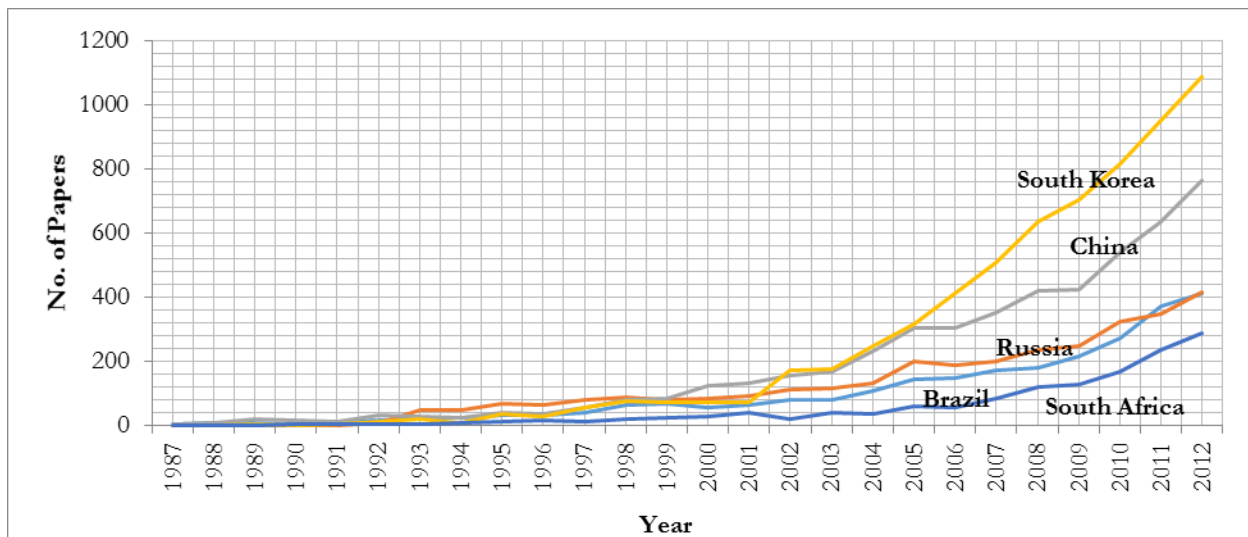
Figure 10: Top Five Collaborating Countries with India



Source: SCI-E

Figure 11 shows; Indian researcher's engagement with other BRICKS countries is increasing. In 2012, South Korea and China have emerged as the third and the fifth most prolific collaborating partner of India.

Figure 11: Collaborative Papers with Scientifically Proficient Countries*

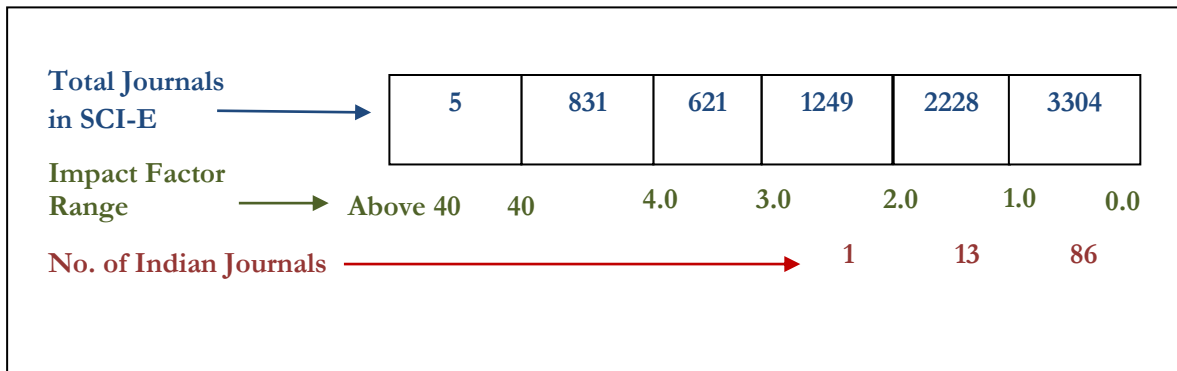


Source: SCI-E; Note: *These countries along with India form the BRICKS countries

⁷ Adams, J. (2013). Collaborations: The fourth age of research. *Nature* Vol. 497, pp. 557–560. doi:10.1038/497557a

Indian Research Impact

Figure 12: Distribution of Indian Journals Impact Factor wise (2011)

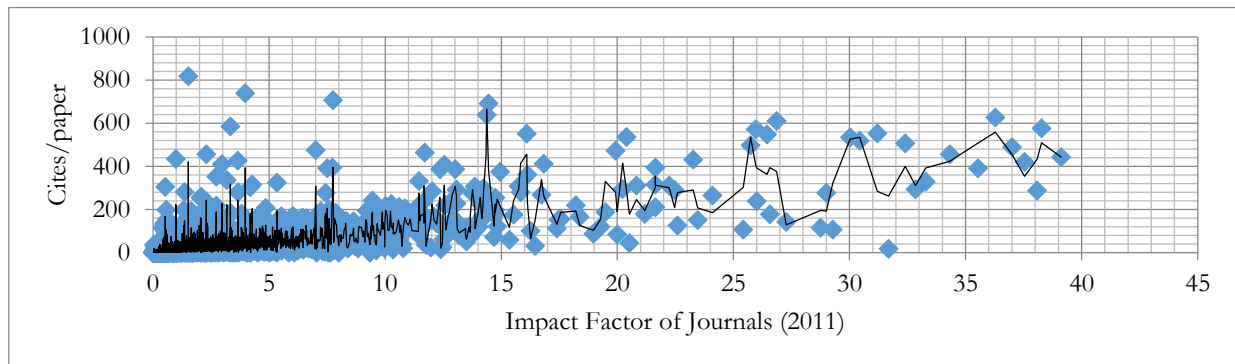


Source: SCI-E and JCR

In spite of increase of Indian journals in the SCI-E, majority of Indian journals have low impact factor. The highest impact factor journal from India is 'Bulletin of the Astronomical Society of India' with impact factor of 2.722. It is an open access journal of the Astronomical Society of India.

Journal Average Impact Factor vs India's Journals Average Impact Factor

Figure 13: Global Publication Distribution of Citation Impact (Cites/Paper) in different Impact Factor Journals (2011)



Source: JCR; Note: In the Figure we have removed four journals having IF ranging from 101-40 for the clarity of Figure. Trend line indicates two-year moving average. Cites/Paper is in respect to the total papers in a journal.

Figure 13 demonstrates that impact factor (IF) is only a crude indicator of papers influence. Some papers attract very high citations (normalized by size). This distribution may vary with the subject field which has not been analyzed here.

Similar relationship between impact factor of journals and citations received by the journals is visible in Indian Journals (Figure 14).

Impact factor of journals is a better reflection of influence in Indian journals covered by the SCI-E (Figure 14).

Figure 14: Distribution of Citation Impact (Cites/Paper) in different Impact Factor Indian Journals (2011)



Source: JCR; Note: Trend line indicates two-year moving average. Cites/Paper is in respect to the total papers in a journal.

The maximum cites/paper by an Indian journals is 27 which is much lower as compared to global cites/paper. The citation impact of papers in Indian journals is however abysmally low.

Has the Quality of Indian Papers Increased with Time?

Observing the citation reception of Indian papers, a 'proxy' judgment can be made of whether influence of Indian papers is increasing or otherwise. The SCI-E covered 51,177 Indian publications in 2010 of which 16,116 papers (31% of total papers) remained uncited (taking 3 year window). In 2008, 47,630 Indian papers were covered by the SCI-E of which 14,836 papers (31% of total papers) remained uncited till 2013 (taking five year citation window). The number of papers that remained uncited from the total publication output in 2008 and 2010 is same. *This shows that Indian papers are now having much higher visibility (taking less time to get cited).*

Table 3: Highly Cited Papers from India

	2000			2006			2012		
	Total Papers (rank)	Top 100 HCP* (rank)	Top 1% HCP** (rank)	Total Papers (rank)	Top 100 HCP* (rank)	Top 1% HCP** (rank)	Total Papers (rank)	Top 100 HCP* (rank)	Top 1% HCP** (rank)
India	19519 (13)	1 (21)	66 (23)	34676 (12)	2 (21)	146 (21)	61821 (10)	3 (35)	340 (20)

Source: SCI-E; Note: *Number of papers present in Top 100 Highly Cited Papers (HCP) from respective country; **Number of papers present in Top 1% highly cited papers from respective country; Source: SCI-E

In spite of increase in research volume (in terms of publications) of emerging economies, the traditionally scientifically advanced countries still attract majority of citations (high influence). Examination of Top 1% highly cited papers in 2012 shows that developed countries like the USA account for 53% of these highly cited papers, Germany 15%, and UK 14%. Among emerging economies, China, has not only increased volume substantially but their papers are also attracting attention; almost 14% of Top 1% highly cited papers are from China in 2012 from 1% in 2000. India has also improved her position in later years in the Top 1% highly cited papers. In year 2000, India contributed only 66 papers in the Top 1% cited papers whereas in 2006 her contribution was 146 and in 2012 was 340. India's increase in research volume do not commensurate with citation reception; it is now among the top 10 countries in research papers but is far below when the ranking is done on citations per paper.

Presence in High Impact Journals

Table 4: Examining Indian Publications in High Impact Journals (2012)

Journal (IF)	Total Papers		Papers from India		Collaborative papers			
	2012	2006	2012	2006	International (Collaborating countries)		Domestic	
					2012	2006	2012	2006
Annual Reviews of Immunology (36.556)	28	25	-	-	-	-	-	-
Cancer Journal for Clinicians (153.459)	37	42	-	-	-	-	-	-
Chemical Reviews (41.298)	183	198	9	2	6 (32)	-	2	-
LANCET (39.06)	1826	1820	44	49	22 (47)	16 (40)	4	5
Nature Materials (35.749)	288	301	-	1	-	1 (1)	-	-

Journal (IF)	Total Papers		Papers from India		Collaborative papers			
	2012	2006	2012	2006	International (Collaborating countries)		Domestic	
					2012	2006	2012	2006
Nature Reviews Genetics (41.063)	158	212	-	1	-	-	-	-
Nat Rev Molecular Cell Biology (37.162)	164	221	-	-	-	-	-	-
Nature (38.597)	2651	2733	15	9	6 (34)	4 (5)	1	-
The New England Journal of Medicine (51.658)	1617	1785	16	12	12 (38)	1 (3)	2	-
Reviews of Modern Physics (44.982)	46	34	1	-	1 (1)	-	-	-

Source: SCI-E

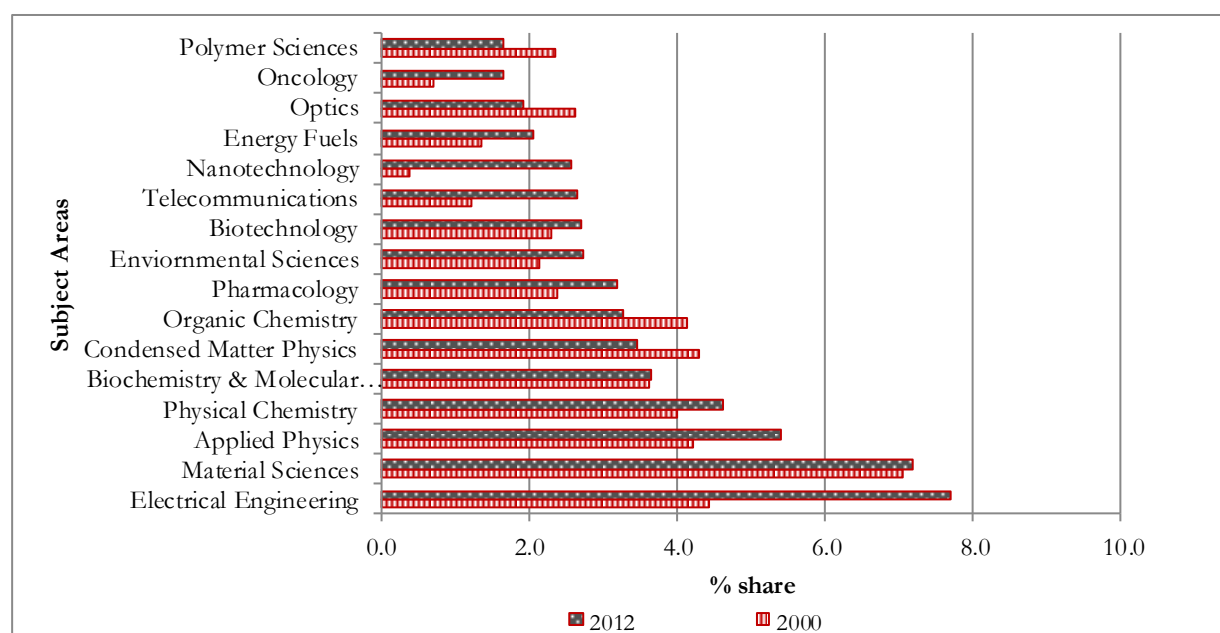
India's publication volume is increasing every year but its visibility in high impact journals is still lacking. This shows that either the quality of paper is not increasing or Indian authors are not targeting high impact factor journals for publishing.

The analysis of Top 1% cited papers and papers in high impact journals shows that international collaboration is an important feature in increasing impact of papers. In Top 1% highly cited papers, in year 2000, 65% of papers were collaborative while only 35% non-collaborative papers. Majority of these collaborative papers were coming from international collaboration i.e. 53% of total papers, while only 12% are domestically collaborative. Similar is the case for papers from year 2006, 69% are collaborative and 54% are internationally collaborative while 15% are domestically collaborative. From 340 papers in year 2012, 78% are collaborative and 63% are collaborating with international institutions.

Similar to the observation in Top 1% cited papers more than 50% of papers in high impact factor journals are collaborative papers. The most active collaborating country with India in terms of number of papers published in the high impact journals are USA (25 papers), England (20 papers) and France (13 papers) (Table 4).

India's Research Strength

Figure 15: Subject-wise Distribution of India's Research Output



Source: SCI-E

Figure 15 exhibit areas where India is actively publishing. One can observe in some cutting edge areas like nanotechnology there has been significant growth in 2012. Relatively lower publication activity in agriculture, and mathematics is an area of concern. *The need for special efforts to strengthen research in the areas of agriculture and mathematics is apparent from the results.*

India is also publishing more actively in areas of developmental concerns and global challenges. In 2012 for example, India published in SCI-E covered journals, 771 papers in Tuberculosis, 5,345 papers in Water, 3,129 papers in Cancer.

Institutional Publishing Profile

Table 5: Institutional Dispersion in Publication Activity

	Total No. of Institutions*	Institutions accounting for 50% of output	Institutions accounting for 25% of output	Total Industries Involved
2000	4,113	5	2 (IIT's; CSIR)	175
2006	8,147	3	1 (IIT's)	126
2012	18,889	11	2 (IIT's; CSIR)	644

Source: SCI-E; Note: *Institutions include the Universities; Research Centers; Industries; Specialized Centers and Foreign Institutions collaborating with Indian Institutions.

Although the number of institutes involved in publishing activity is increasing over the years, however it is highly skewed in terms of publishing frequency. As an entity Indian Institute of Technology (comprising 16 IITs) and CSIR Laboratories (comprising 39 laboratories) contribute almost 25% of India's publications. Activity of prolific institutes are highlighted in Table 6.

Table 6: Prolific Indian Institutions in Research Publications

Institutions	2006		2012	
	No. of papers	% share	No. of papers	% share
Indian Institute of Science	1,378	4.0	1,774	2.8 ↓
Bhabha Atomic Research Center	837	2.4	1,478	2.3 ↓
IIT-Kharagpur	1,056	3.0	1,314	2.1 ↓
All India Institute of Medical Sciences	752	2.2	1,127	1.8 ↓
IIT-Bombay	745	2.1	1,074	1.7 ↓
Delhi University	562	1.6	1,039	1.7 ↑
Banaras Hindu University	493	1.4	1,035	1.6 ↑
IIT-Madras	771	2.2	1,030	1.6 ↓
IIT-Delhi	835	2.4	1,007	1.6 ↓
IIT-Kanpur	736	2.1	866	1.4 ↓

Source: SCI-E; Note: % share with respect to total Indian output.

The number of firms involved in publication activity has increased more than 50% in 2012 from that in 2000 (Table 5). Most of these firms are multinational entities (primarily their R&D centers) in India. Active collaboration with Indian universities and research institutes are observed. Some of the firms actively involved in publications are listed in Table 7.

Table 7: Indian Industries Actively Involved in Publishing*

2006		
Industry	Papers	No. of Collaborative Institutions (Major Collaborators (papers))
Texas Instruments*	17	3 (IITs (2); Oregon Univ. (2); IISc (1))
Ogene Systems	16	3 (CSIR (32); Univ. of Tokyo (1); Institute Rech Catalyse (1))
Laxmi Fumigat Pest Control	15	20 (APS Univ. (13); Bareilly Coll. (4); Holkar Model Autonomous Coll. (4); Univ. of Florence (4))
GE India Technol Center*	11	9 (IITs (2); Nanyang Technological Univ. (2); Oregon Univ. (2))
Fluent India*	6	2 (IIT (6); IISc (1))
Reliance Life Science	5	14 (John Hopkins Univ. (2); Bresagen (1); Cellartis (1))
2012		
Astrazeneca India*	16	6 (Univ. of Hyderabad (2); Uppsala Univ. (2); Southern Illinois Univ. (2))
GVK Bioscience	18	Jawaharlal Nehru Technological University (11); Andhara Univ. (2); University of Tokyo (2))
Texas Instruments*	15	16 (IITs (8); University of Maryland (4); IISc (2))
Therachem Research Medilab	12	-
Heron Health*	12	2 (Mayes Coll. Healthcare business Policy (1); PFIZER (1))
GM Technology Center*	11	5 (GEN Motors (2); CSIR (1); IISc (1))
Reliance Life Science	9	11 (Anisha Clinic (1); BARC (1); Apollo Victor Hospital (1))
Incozen	8	10 (JNTU (3); Rhizen Pharma (3); TG Therapeutics (2))
Dr. Macs Biopharma	7	5 (JNTU (6); Univ. of Tokyo (4); GVK Biosciences (2))

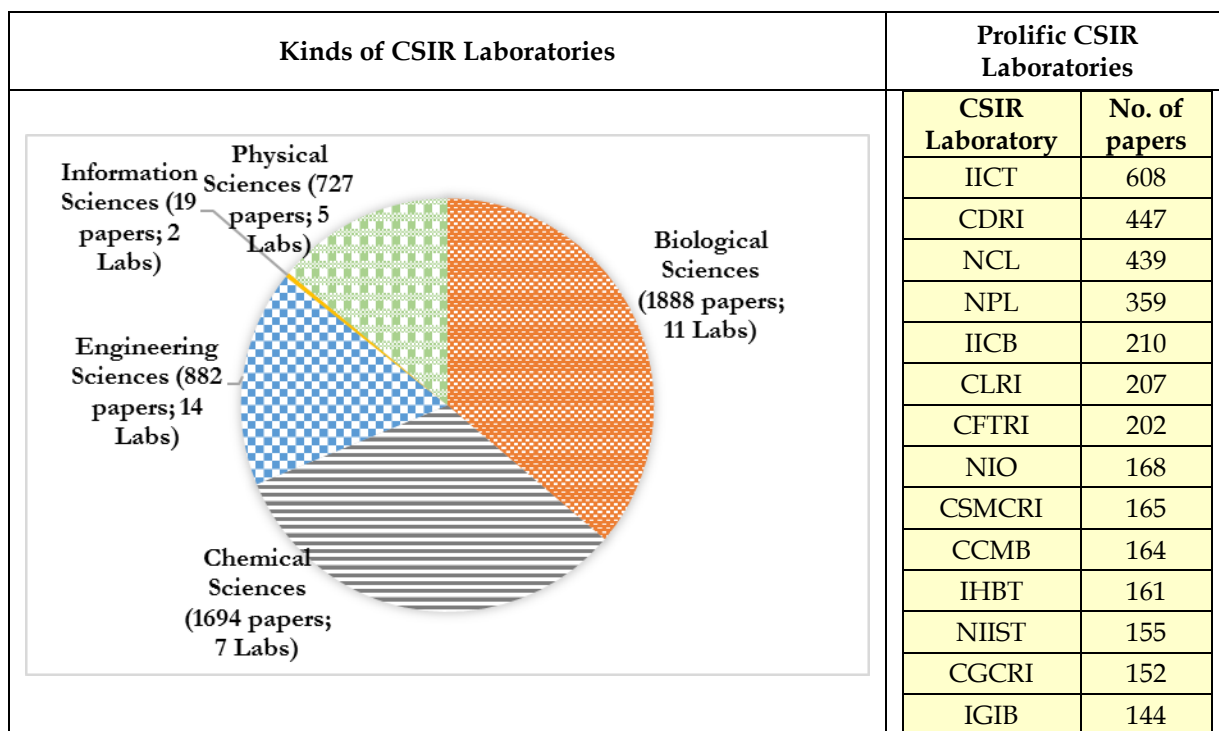
Source: SCI-E; Note: *Firms primarily (their foreign R&D centres) in India

The relative absence of Indian firms as seen from the above table is a cause for concern.

Council of Scientific and Industrial Research (CSIR)

CSIR play an important role in strengthening research activity of India. Research profile of CSIR provide indication of India's research direction. CSIR consist of a network of 39 laboratories and 80 field centers which spans the geographical dimensions of India which carry out fundamental and applied R&D in all areas of science and technology. The distribution of scientific research output from CSIR Laboratories is given in Figure 16.

Figure 16: Publication Distribution Among Different CSIR Laboratories (2012)



Source: SCI-E

CSIR Laboratories are collaborating with industries from India as well as from other countries. Some reflection of this comes from joint research activity with industry (Table 8).

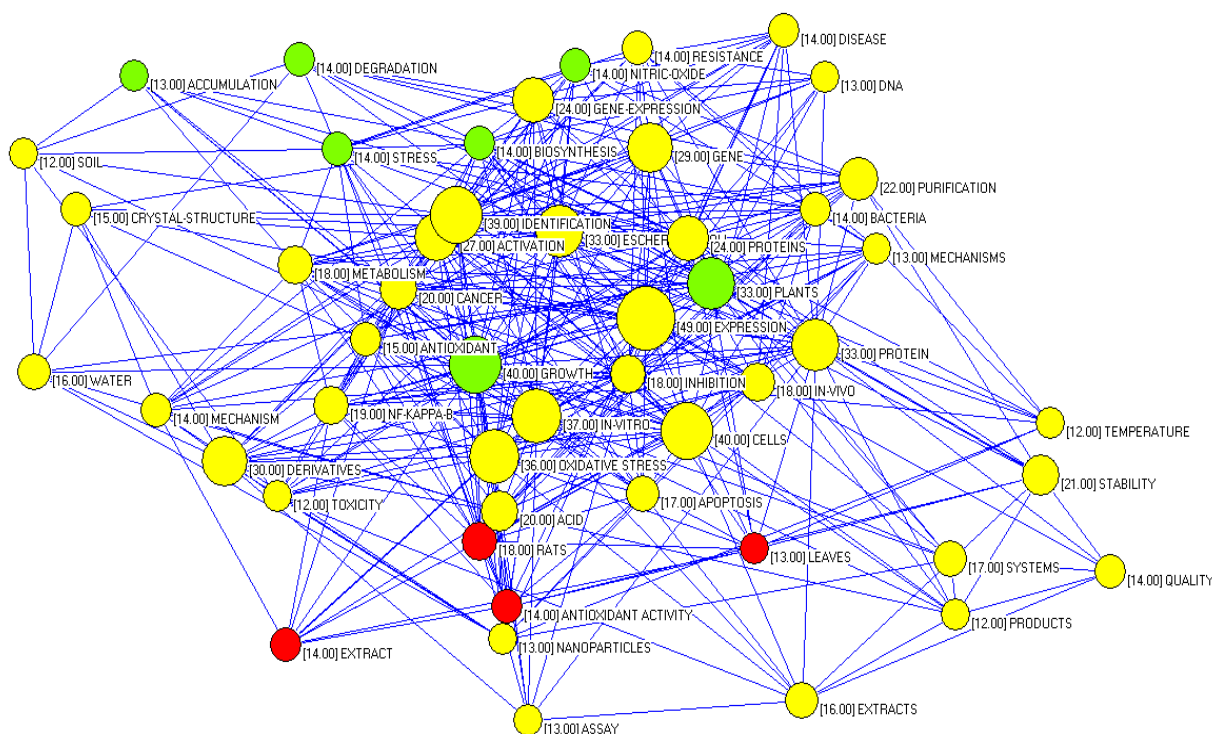
Some of the Industries collaborating with CSIR Laboratories are listed in Table 8.

Table 8: Industries Collaborating with CSIR Laboratories(2012)

Industry	Collaborating CSIR Laboratory
Mylan Laboratories*	CDRI (4 papers); NCL (3 papers)
Tata Steel	CMERI; IICT; IMMT; CGCRI; NML; CLRI (1 paper each)
Rubamin	IICT (5 papers)
Dr Reddys Laboratories	CDRI (4 papers)
Novartis Pharmaceuticals*	CDRI (4 papers)
Piramal Healthcare	CDRI (4 papers)
Ranbaxy Laboratories	CDRI (4 papers)
Sun Pharma	CDRI (4 papers)
Balmer Lawrie	CLRI (3 papers)

Source: SCI-E; Note: *Includes Foreign R&D Centers in India

Figure 17 : Linkages Among Prolific Concepts in Biological Sciences*(2012)



Note: *Based on keywords assigned by SCI-E in each paper from laboratories under Biological Sciences. Linkages between keywords with frequency more than 49. Size indicates the frequency of occurrence of the keyword. Color implies keywords connected more intensively; Analysis using Bibexcel and visualization using Pajek.

The most frequent clusters visible (Figure 17) include the applications of in vivo and in vitro techniques in the study of cancer and other tumor related diseases, diseases in plants etc; evolutionary studies using proteomics in various organisms like E.coli; Intervention of nano-complexes and various other organic complexes as antibiotics for different purposes. Apart from this some of the frequently occurring keywords indicate the CSIR research in the direction of drug discovery; infectious diseases like tuberculosis; encapsulated biomolecules as carriers.

Final Remarks and Policy Implications

Global publication activity over a period of time exhibits exponential growth. Key drivers that shape this distribution are: Expansion of journal coverage in major bibliographic databases, Emergence of new research areas, Increasing Scientific activity of Emerging Economies, and Significant rise in International Collaboration. The increasing publication activity globally can be linked to the countries spending more in R&D which is making available more resources for scientific research. 'Return to Investment' i.e. amount of spending in R&D and its outcome in terms of research publications is a crude measure but nevertheless provides some indication of efficiency. India scores highly in this i.e. spends the least amount among the comparator countries in producing research papers.

Indian publications have shown exponential growth from 2000 onwards. Along with expansion of journal coverage in global bibliographic databases, inclusion of a large number of Indian journals; more institutes now involved in publishing activity; increase in international collaboration are major factors behind the publication growth. In emerging areas, India is visible among the top publishing countries which is also driving her publication growth.

Only a few Indian firms are involved in publishing activity. Foreign firms in India are contributing to majority of industry papers. Many of these papers are co-authored with Indian universities and research institutions. Thus foreign firms are increasingly

engaging with Indian research ecosystem. The increase in volume (research papers) does not commensurate with India's citation profile. Indian papers visibility in highly cited papers, high impact factor journals are abysmally low.

Some major policy implications that emerge is the increasing need for the country to devote higher investment in R&D. In cutting-edge science based technology areas Indian researchers are actively publishing. Particularly in these areas there is a need for engagement with industry (joint research work) that would strengthen translational activity. Indian researchers need to publish in journals that are regarded as important journals by the research community in a field/subfield (high impact factor journals in a field/subfield is one indication of this). This would lead to higher visibility of Indian research activity. Indian journals have low impact-factor. Peer review system, editorial policies, timeliness of journal publication are some of the key factors that need to be addressed for attracting high quality research papers. Only a few institutes account for majority of research publications. More efforts are required to correct this imbalance.

This bulletin be cited as:

Bhattacharya, S., Shilpa and Kaul, A.(2014).'*Scientific Research in India: Drawing Insights from Bibliometric Indicators*'. ISTIP Bulletin No. 3, CSIR-NISTADS.

For suggestions/feedbacks, please contact: sujit_academic@gmail.com