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Emerging countries assertion in the global publication landscape of science: a case study of India

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Abstract Global landscape of scientific activity is changing and becoming more diverse with emerging economies particularly China redrawing the contours of scientific research in the twenty-first century. Research publications, the most cherished output of science, provides robust evidence of this changing landscape. The global publication share of advanced scientific countries is decreasing with significant rise in publication share of China and also of other emerging economies such as India, South Korea, and Brazil. Their publications though are still lagging in global reception as measured through citations. However, with increasing international collaboration and publishing in promising areas and high impact journals, the citation reception of their papers is increasing. Indian publication growth is much behind China whose growth has been dramatic! However, India's emergence is interesting as from a leading country among developing economies in scientific publications till early 1980s, her publication growth exhibited sharp decline in the late 1980s. Only from 1995 onwards India started making an assertion in the global publication race and in some promising areas of high relevance such as nanotechnology her publication growth has been impressive. India to a large extent epitomises the scientific activity of emerging economies. Thus through the lens of India's publication trend, the paper underscores the changing global landscape of science. To place India's publishing activity in proper context, the paper broadly examines the publication activity of some advanced OECD countries and BRICKS (Brazil, Russia, India, China, South Korea and South Africa) countries. Implications of this study are discussed.

Keywords India · BRICKS · Publication growth · Citation impact · Science policy

Disclaimer: The opinions, estimates and finding contained in the research paper are based on the information available at the date of publication. The views in this study are those of the authors. Inquiries may be addressed to the corresponding author.

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Introduction

The twenty-first century is now commonly called as knowledge driven or knowledge-based economy (OECD 1996; Montgomery 1999). Sveiby (1997) has calculated more than fifty percent of the fastest growing companies in the US as knowledge-based companies. The business success of these companies is driven by knowledge-based activities; creating intangible intellectual assets and exploiting them. The commercialisation of knowledge as means of stimulating competitiveness and growth is becoming an increasingly important strategic instrument across the globe. Computer science, biotechnology, nanotechnology, synthetic biology are some of the signature disciplines that drive new technologies in the twenty-first century.[1] Scientific competency and capability of transforming raw outputs of science and technology into tradable commodity is becoming a key ingredient for wealth creation for firms, regions and nations at large. Locations that have the capacity to create knowledge and mechanisms for translation have emerged as leading economic regions globally (Huggins and Izushi 2007). Firms in the new technologies increasingly want to co-locate in regions where there is possibility of interface with academia and institutional mechanisms for laboratory to innovation translations (Dolfsma 2008). Traditionally science based companies co-locate in knowledge clusters in advanced OECD (The Organisation for Economic Co-operation and Development) countries. FDI (Foreign Direct Investment) in R&D (Research and Development) are also traditionally in advanced OECD countries where knowledge based activities are predominant. However, in the last few decades the scenario is changing with knowledge driven companies increasingly co-locating in newly developed science parks in emerging economies especially in China, South Korea, Taiwan (Sandhya et al. 2013). The flow of FDI in R&D has also been significant in these countries. India, Brazil and other emerging countries are also attracting FDI in R&D, knowledge based companies and foreign R&D centers (Doz et al. 2006; Krishna et al. 2012). Another trend is the emergence of knowledge based firms in newly industrialized and emerging economies, for example, in South Korea, Taiwan, Singapore, China, India, and Brazil. South Korean firms have become global players and a few firms from China, India, and Brazil are also following this trend (Agtmael 2007).

It is becoming important therefore from economic, policy and strategic viewpoints to uncover the scientific competency of nations or regions (see for example US NAS, NAEIM 2005). Some of the questions that are being asked are: What are the key ingredients that are driving the cutting edge scientific research? Which are the major hubs of scientific research? Is the global landscape of science changing? Are new regions emerging as centers of knowledge creation? What are the determinants of this change? In last few years there have been a series of influential studies that have thrown light on the above questions. UNESCO (2010) report 'The current status of science around the world' underscores the growing role of knowledge in the global economy. The report highlights the support system of science is changing and emerging economies especially China and South Korea are increasing outlay for science, involving more people in research and developing world class institutions. Particularly, the report posits a new Triad in scientific publications of

[1] America's President Barack Obama, State of Union Address at The White House (25 January, 2010). *Strategy for American Innovation: Catalyze Breakthroughs for National Priorities* (http://www.whitehouse.gov/innovation/strategy/catalyze).

BRIC (Brazil, Russia, India, and China) countries with impressive growth rate (with the exception of Russia). The report shows that USA is still the leading publishing country but Japan and Germany have fallen behind China and share of all the three top publishing countries (USA, Japan and Germany) decreasing significantly. Royal Society in 2010, 'The Scientific Century Securing our Future Prosperity' underscores the emergence of multi-polar, networked system of global science and innovation. Keeping this in context, it focusses on what needs to be done by the UK to compete more successfully in science and innovation. Another set of influential studies by Demos under the series 'The Atlas of Ideas: Mapping the new geography of science' examines the science and technology-based innovation competency of India (Bound 2007), China (Wilsdon and Keeley 2007) and Brazil (Bound 2008). Another influential report by Royal Society (2011) 'Knowledge, Networks and Nations' surveys the global scientific landscape, noting the shift to an increasingly multipolar world underpinned by the rise of new scientific powers such as China, India and Brazil; as well as the emergence of scientific nations in the Middle East, South-East Asia and North Africa. The study highlights how the scientific world is becoming more interconnected, with international collaboration on the rise. Using publication as an evidence it underscores this fact by showing that over a third of all articles published in international journals are internationally collaborative, up from a quarter, 15 years ago.

These reports have drawn liberally from contemporary studies, for example, Gibbons et al. (1994), Wagner (2008) to make their claims. Increasing 'South–South' collaboration is also playing role in the changing global dynamics of science. Collaborative arrangements to develop common framework and support system are influencing these collaborations. Some of the collaborative arrangements are formation of 'BRICS' involving five large economies Brazil, Russia, India, China, and South Africa, similarly 'IBSA network' involving India, Brazil and South Africa. Solving challenging developmental problems through scientific intervention, and developing capability in cutting edge research fields through joint effort are key areas underpinning these groupings. IBSA, for example, has identified nanotechnology, oceanography, and Antarctic research for collaboration.[2] One important observation from the above studies is the extensive application of bibliometric data to uncover the research landscape of global science. Royal Society (2011) has drawn attention to this '*it is clear that bibliometric data alone do not fully capture the dynamics of the changing scientific landscape. However, they presently offer the only recognized and most robust methodology for doing so*'.

Bibliometric based studies have provided further insights into the global landscape of science. Kostoff et al. (2007a) highlights how across different disciplines China and India are more visible globally. China's progress is remarkable as in many disciplines it is challenging dominance of OECD countries. Glanzel et al. (2008) examines the publication profile of emerging countries vis-à-vis the triad countries (USA, EU and Japan). The study highlights the relative decline of the triad, attributing this to the changing balance of power in scientific production. A series of recent reports and bulletins by Evidence and Science Watch (Thomson Reuters), Elsevier among others have examined the contemporary geography of science through bibliometric approach. These reports draw attention to the changing global landscape reasserting the observations/findings of studies that have examined global research landscape through qualitative application of diverse STI indicators. Trends from the above studies indicate that newly industrialized economies (South Korea, Singapore, for example), and transition economies (China, India, Brazil, Iran, Singapore,

[2] http://www.ibsa-trilateral.org/.

for example) are challenging the global research publication dominance of advanced OECD countries. The important signal from the publication trends of newly industrialized and transition economies is their presence in some key science based technological areas. One of the new promising area is nanotechnology where one can observe that these countries are in the league of advanced OECD countries particularly in publication activity (Bhattacharya et al. 2012b). Hassan (2005) points out that nanotechnology is emerging plausibly as a first cutting-edge research field where the emerging economies are not followers but are in league with North countries.

Examining evidence of quality as uncovered through citation analysis however, provides a different picture. It shows that the citation reception of papers from emerging economies does not commensurate with publication volume. Kostoff et al. (2007b, c) has shown that papers from both China and India are not attracting expected citations. However, they have pointed out that international collaboration is helping them to publish papers in journals globally visible and of high impact. Leydesdorff and Wagner (2009) showed that although developed countries like USA and EU are losing in global publication share, but in terms of citations they are major players. Moiwo and Tao (2013) study highlights that although China is leading in publications but it still lags behind other developed nations in some other publication attributes like citations received by their papers, publications normalized with population and GDP, etc. A recent study by Winning (2014) using 'web-of-science' and 'Derwent world patent index' asserted that the scientific and technological gap between North and some South countries are closing. The study further draws attention to the improving citation impact of emerging countries papers. Adams (2012, 2013) attributes this to the emergence of research networks with increasing participation of emerging economies changing the global balance of research activity.

The above studies in general point out to the changing global research landscape of science with emerging economies particularly China influencing the research landscape. These studies also highlight the emergence of India, South Korea, Brazil, etc. Thus, these studies provide the context to examine more closely the research profile of emerging economies in more depth; to inform further the salient aspects of the changing research landscape. The studies on scientometric analysis of India's publications provides more informed understanding of India's research trends. Raghuram and Madhavi (1996) examined Indian publication activity in the SCI for the period 1981–1995. Their study showed that India is losing in global publication race in both quantity and quality. Basu (1999) extended this discussion by emphasizing that critical reason behind this decline was decrease in the number of Indian journals covered by the SCI database. It was argued that Indian researchers have increased their publication activity if one negates the effect of delineation of Indian journals from the database. Thus the observation of Indian researchers not performing was contested. Kostoff et al. (2007c) study based on SCI-E showed that from 1995 onwards Indian research publications are rapidly increasing. However, the study pointed out low visibility of Indian papers. Thus the study posited that this may be due to half the journals that contain most of the Indian papers are domestic Indian journals, and they have low impact factors. This study also highlighted that collaboration have positive impact on the quality of papers as measured through citations.

Demos study by Bound (2007) drawing both from qualitative and quantitative evidence primarily pointed out the emerging research and innovation landscape in India. Among the findings of this study are that Indian scientists are collaborating more internationally. The report highlighted the importance of education to collaboration, pointing out the ever-growing collaboration with USA due to Indian students and scholars preferring USA as most important destination for higher education. International collaboration was again found to be an important contributor of India's publication growth and attracting visibility by Evidence (2011) and Elsevier (2012). The Evidence study based on SCI-E and Essential Science Indicators showed that 18.8 % of Indian research publications in 2001–2005 were internationally co-authored, and this increased to 19.5 % in 2006–2010. The study further highlighted that the average citation impact of these internationally co-authored works was significantly higher than the overall average. Elsevier (2012) study based on Scopus database showed that growth rate of India's publication during the time period 2006–2010 was increasing at compound annual growth rate of 12.3 % per year. Only two countries China (13.7 %) and Iran (25 %) exhibited higher growth rate than India. This study also showed that international collaboration is contributing to volume and influence (higher citation reception). Panat (2014) analysis of research output of India and China in SCI-E showed that although India's output was increasing at a very fast pace but China's growth was far greater than India. Findings of Kostoff et al. (2007a) for the period 1980–2005 with China outperforming India very rapidly is thus seen in the contemporary period also. One major issue that emerges from the above studies is that Indian research publications have significantly increased over the period, however her papers visibility is still lagging but do show positive trend.

The present study aims to contribute to the above research by examining some salient aspects of India's research activity. The global landscape of research publications and of BRICKS (Brazil, Russia, India, China, South Korea, and South Africa) countries are explored to place Indian research profile in proper context. *We posit that this will inform and enrich the present debate on the changing global landscape of science further.*

Objectives

The present paper examines Indian publication profile to explore reasons behind India's publication growth. It also examines her publication impact from a set of citation based indicators to underscore to what extent India is positioned in the quality debate. To put India's publication activity in proper context, the study looks at the global landscape of science, comparator set based on BRICKS countries and explores how their changing contours effects India's publication trends. India to a large extent epitomises the scientific activity of emerging economies and thus many of the issues raised can have wider implications which are discussed.

Methodology

The study is based on data extracted from the two major global bibliographic databases, the Science Citation Index-Expanded (SCI-E) and the Scopus for the period 1990–2012. The study also draws from the Journal Citation Report (JCR). Publication and citation based indicators are applied to examine global trends, and Indian publication activity in details. Comparison with advanced OECD countries and BRICKS is undertaken for 2006 and 2012 to discern whether there is tangible shift in the global publication landscape. To place Indian publication activity in proper context, her publication activity is compared with BRICKS countries. BRICKS includes transition and newly industrialized economies and thus provides a useful comparator set. Percentages of world share are based on attributing whole count to each country in the case of internationally co-authored papers.

To make a stronger assertion of the claims/findings, statistical tests were performed using SPSS version 20. Lorenz curve (or concentration curve) was applied to measure the dispersion of papers among OECD countries, and 'Non-OECD countries'. The Lorenz curve is a function of the cumulative proportion of ordered countries mapped onto the corresponding cumulative proportion of number of papers given by $L(y) = \int xd\ F(x)/\mu$, where, $L(y)$ is Lorenz function, $F(x)$ is the cumulative distribution function of ordered countries, and μ is the average size. If all the countries have equal number of papers then Lorenz curve will be a straight line called the line of equality, otherwise more the inequality more shifted will be that line from the line of equality. To compute the total amount of inequality we calculated the Gini coefficient. It is the ratio between the area enclosed by the line of equality and the Lorenz curve, and the total triangular area under the line of equality.

Levene's test and t statistic was calculated to test whether the difference between means of publication output of advanced OECD and BRICKS is statistically significant or not. Levene test is applied to test the null hypothesis that the variances of two groups (i.e. advanced OECD and BRICKS countries) are equal or otherwise. As it was established that the assumption of homogeneity of variance is met, it was appropriate to undertake the *t test itself* (Field 2005). Even if the value of t statistics is not significant, it is useful to calculate whether the effect is still substantive or not based on r value calculated as $r = \sqrt{(t/t + df)}$ (Rosenthal 1991; Rosnow and Rosenthal 2005). The r value of 0.10 indicates small effect, 0.30 medium effect and above 0.5 large effect (Field 2005).

Results and discussion

Figure 1 maps the 'percentage share of world R&D' with 'GERD as percentage of GDP' for selected advanced OECD and BRICKS countries.

The horizontal axis (x-axis) which captures the dimension of absolute funding by each country with respect to overall global funding provides some important indications of a

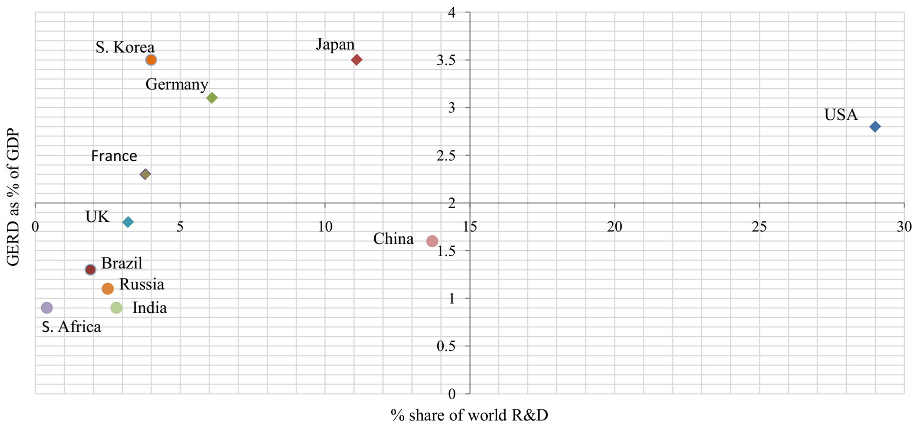

Fig. 1 R&D statistics of the countries examined in this study (2012*). *Source*: NSF (National Science Foundation) (2013), OECD Stat (2013), Eurostat (2012), and UNESCO report (2010); *Note*: Figures of GDP (Gross Domestic Product) and GERD (Gross Domestic Expenditure on R&D) are in US billion dollars; *2012 or latest data available

country's capacity to invest in R&D. USA is the overall leader with a wide margin in comparison to other countries. It is contributing more than twenty-five percent of research funding in global comparison. It is however striking to see China's emergence as the second most active funding of R&D in global comparisons. This implies China now has large capacity to fund R&D. On the other hand 'priority' of a country towards R&D w.r.t. its overall GDP is captured by the vertical axis (*y*-axis). One can observe except UK, all the other five advanced OECD countries are spending more than 2 % of their GDP on R&D. This shows high priority to R&D given by advanced OECD countries. UK with 1.8 % is also not an outlier. On the other hand, we observe among BRICKS it is only South Korea that has very high value in this index.

Thus the two input indicators show advanced OECD countries strong commitment and also capacity for investment in R&D activities. In advanced OECD countries, the ratio of investment is approximately 1:2 with industry investing almost twice then that of government's contribution (Battelle and R&D 2012). On the other hand in majority of BRICKS and other developing countries it is the other-way around. This lack of industry commitment makes overall capacity to invest in R&D activities less in these countries. China and to some extent South Korea is shifting away from the pattern shown by other emerging and developing economies. Huge outlay for R&D is surely one of the major drivers behind China and South Korea's emergence in the global STI (Science, Technology and Innovation) landscape in recent years. Along with government commitment, industry commitments are also increasing in these countries (Battelle and R&D 2013). The picture however is becoming less uneven for BRICKS and some other rapidly emerging economies when one examines investment in emerging areas i.e. technological fields that are science based. In nanotechnology, for example, major outlays by all the BRICKS countries and other emerging economies are observed (Hassan 2005).

Global publication trend

The global publication pattern shows transition from steady growth to exponential behavior in the year 2000 (Scopus), and 2003 (SCI-E).

Figure 2 shows that the doubling time for absolute publications covered by the Scopus and the SCI-E, taking 1990 as the base year, is 15 and 18 years respectively. Publications covered by the Scopus increased by 50 % in 2000 from that in 1990 whereas i*t 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 %*. Publications covered by these

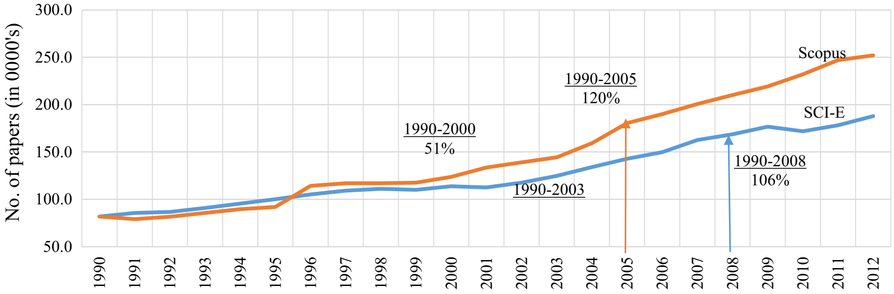

Fig. 2 Publication trend of global research output (1990–2012)

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, publication increased by 8.5 %. *The findings are interesting and striking as it exhibits that scientific research is moving at a much faster pace than imagined!*

A major reason behind global publication growth can be seen from the increasing scientific activity of advanced OECD, emerging and newly industrialised economies (Fig. 3).

China is contributing a large extent to the overall growth of papers from BRICKS countries. But other BRICKS countries particularly India and South Korea are also rapidly expanding their output. As Winning (2014) has rightly commented that "only in comparison to China, India's research output look like underperformance—it is in fact impressive growth". This we also show later in this study. This observation is also true for South Korea.

Lorenz curve (or concentration curve) was applied to measure the inequality in publication/dispersion among OECD countries, and among Non-OECD countries. Figure 4 shows the results obtained by application of Lorenz function.

The concentration curve shows that in case of Non-OECD countries the countries are more unequally distributed as the curve is farther from the line of equality then in the case of OECD countries. The Gini coefficient for OECD and Non-OECD countries are 0.47, and 0.67 respectively. The Gini coefficient further demonstrates the inequality in publication profile of Non-OECD countries in comparison to that of OECD countries. Examining the statistics further, we see that the concentration curve of OECD countries is largely defined by the USA and for the Non-OECD countries by China. This result is not surprising as similar conclusions are coming from recent studies. Germany, England, Japan in OECD and India, Brazil in Non-OECD also exhibit major influence on the concentration curve. However, almost all the countries of OECD (32 countries) have substantial influence in shaping the concentration curve. This is unlike the case of Non-OECD countries where only nine countries (total countries 176) play substantial role in shaping the distribution. Figure 5 provides further evidence of the changing global research landscape.

Figure 5 shows that the share of advanced OECD countries are decreasing but on the other hand share of BRICKS countries are rapidly raising. This rising publication share of BRICKS countries implies that balance of research publications will be shifting more towards this block of countries in future. China again exhibits the major rise in share which

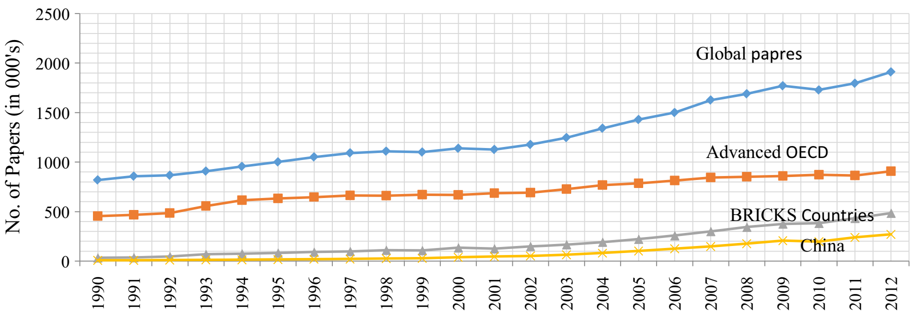

Fig. 3 Publication trends of globally and by BRICKS countries, advanced OECD countries and China (1990–2012). *Source*: SCI-E

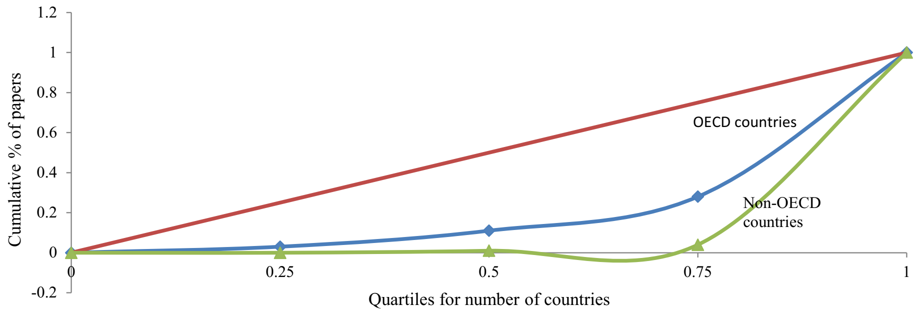

Fig. 4 Lorenz curve indicating inequality in publication among OECD and Non-OECD countries (2012)

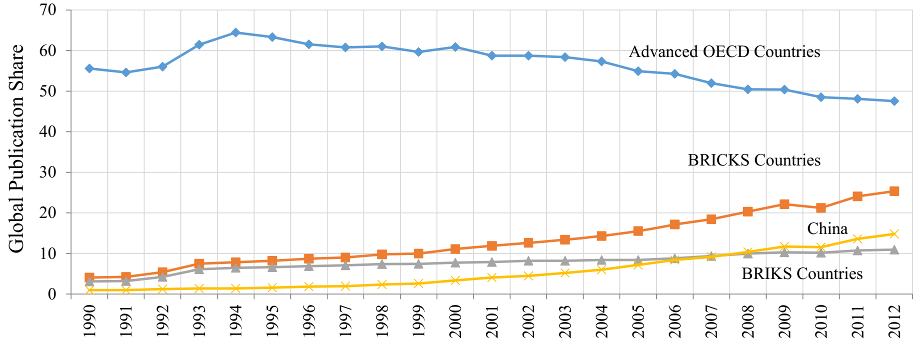

Fig. 5 Publication share by advanced OECD, BRICKS and BRIKS countries, and China (1990–2012). *Source*: SCI-E; *Note*: BRIKS includes all the BRICKS countries except China

implies that it will in future emerge as the leading country in research publications. It is important to probe the trends analytically to discern further meaning i.e. statistical validity of the statements. We undertake independent *t* test to examine whether the difference between means (publication output of advanced OECD countries and BRCKS) is significant or otherwise. Table 1 provides descriptive statistics of the publication means of

Table 1 Descriptive statistics of papers published by two groups of countries

Country	*N*	Mean	SD	SE Mean[a]
2006				
Advanced OECD (top six countries)	6	146,932	145,962	59,589
BRICKS countries	6	43,315	42,189	17,223
2012				
Advanced OECD (top six countries)	6	159,013	151,158	61,710
BRICKS countries	6	79,796	95,260	38,890

Source: SCI-E

[a] Standard error is the standard deviation of the sampling distribution which shows that how variable the differences between sample means are by chance alone

Table 2 Independent sample test

	Levene's test for equality of variances		*t* test for equality of means						
	F	Sig.	*t*	d*f*	Sig. (2-tailed)	Mean difference	SE difference	95 % confidence interval of the difference***	
								Lower	Upper
2006									
EVA*	2.877	0.121	1.670	10	0.126	103,617	62,028	−34,590	241,824
EVNA**			1.670	6	0.147	103,617	62,028	−49,241	256,475
2012									
EVA*	0.613	0.452	1.086	10	0.303	79,217	72,942	−83,309	241,742
EVNA**			1.086	8	0.308	79,217	72,942	−87,505	245,938

* *EVA* equal variances assumed; ** *EVNA* equal variances not assumed; *** 95 % of intervals would include the unknown parameter in the respective range of lower and upper values

advanced OECD and BRICKS countries for 2006 and 2012. For year 2006 as well as 2012, on average, advanced OECD countries have greater publication mean then BRICKS countries. However, the difference between means is decreasing in 2012 from that in 2006 showing that the publication profile of advanced OECD countries and BRICKS is coming closer. We undertake statistical tests to draw valid claim about the publication profiles of the two groups.

Levene's test was undertaken to test the hypothesis that the variances of two groups (i.e. advanced OECD and BRICKS countries) are equal. The result (Table 2) shows that Levene's test is not significant in both 2006 and 2012 as p values are >0.05. *Thus, the null hypothesis that differences between variances is roughly equal is not rejected* Thus we will read the statistics of the row 'equal variances assumed'. Having established that the assumption of homogeneity of variance is met, we undertake the *t test itself* (Field 2005). The value of t significance is >0.05 for both the years i.e. 2006 and 2012 (Table 2). The *t statistics exhibiting non-significant implies that there is no statistical difference between means of publication output of advanced OECD and BRICKS countries.* The calculated r value is <0.1 for both 2006 and 2012, implying that the difference between the means is also highly non-substantial (Field 2005).[3] This further asserts that difference between the two profiles is non-existent in both the periods.

India's publication trend

India in 2012 became the 7th and 10th most active publishing country based on publications covered by the Scopus and the SCI-E respectively. The publication trend in both these databases is shown in Fig. 6. Shrivats and Bhattacharya (2014) demonstrated that from year 2002 onwards, the publication curve starts changing from linear to an exponential growth pattern. Their study based on Scopus showed the regression equation

[3] Sometimes even if we observe that the result is non-significant, r values can indicate that the difference do exits. The r values of 0.10 indicates small effect, 0.30 medium effect and above 0.5 large effect (Field 2005).

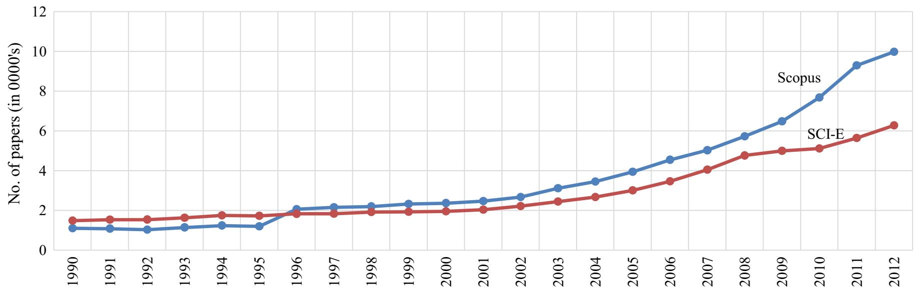

Fig. 6 India's publication trend (1990–2012)

describing the pattern was $O = 1E - 111e^{\wedge}0.1326t$ (R^2 fit of 0.9963).[4] SCI-E trend also exhibited similar exponential fit.

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.

We examine the plausible reasons behind India's publication growth.

(a) *Expansion of journals in global databases and inclusion of Indian journals*

The SCI-E and the Scopus are increasing their journal coverage year-on-year. In the SCI-E for example, the number of journals increased from 6536 journals indexed (in year 2000) to 8903 journals indexed (in year 2012). The Scopus exhibited more significant increase during the same period, from 10,953 journals (in year 2000) to 19,988 journals (in year 2012). Indian journals are also being indexed more in both the SCI-E and the Scopus. Figure 7 highlights the Indian journals indexed in the SCI-E and the Scopus for the year 2005–2012.

The figure highlights the increase of Indian journals in both the databases. The SCI covered 36 Indian journals in 1980 which declined to 10 journals in 1997. This had a major effect on Indian publication in the SCI-E as it was shown by Basu (1999) that the average number of papers originating from India in an Indian journal in the SCI is more than 100 per year as compared to only five such papers on average in any other SCI journal in which Indian papers appear. The SCI-E has again started indexing a number of Indian journals (Fig. 7a), which has significant effect in the increase in Indian publications. On an average it has been observed that more than 50 % of the papers in the Indian journals have papers from Indian authors. Similar trend is observed from the Scopus. The Indian journals indexed in Scopus increased from 164 to 362 from year 2005 to 2012 respectively. *Thus inclusion of Indian Journals in the SCI-E and the Scopus has major effect on India's publication trend.*

(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 growth. There were 8147 institutions involved in publishing activity in 2006 which increased to 18,889 in 2012. However, institution wise publication is highly skewed with only a few institutes accounting for majority of publications. As an entity, Indian Institute of Technology (comprising 16 IITs) and CSIR

[4] O represents India's overall publication.

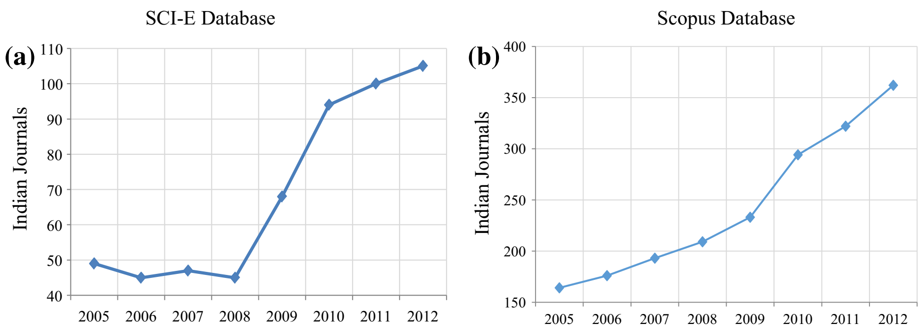

Fig. 7 Indexing of Indian journals in the SCI-E and the scopus (2005–2012)

Table 3 Institutional dispersion in publication activity

	Total no. of institutions[a]	Institutions accounting for 50 % of output	Institutions accounting for 25 % of output	Total industries involved
2000	4113	5	2 (IIT's; CSIR)	175
2006	8147	3	1 (IIT's)	126
2012	18,889	11	2 (IIT's; CSIR)	644

Source: SCI-E

[a] Institutions include the Universities; Research Centers; Industries; Specialized Centers and Foreign Institutions collaborating with Indian Institutions

Laboratories (comprising 39 laboratories) contribute almost 25 % of India's publications. Table 3 highlights this skewed institute wise publication activity.

It is important to uncover reasons behind this substantial increase in number of institutes involved in publishing activity. One can observe from Fig. 7a that there has been a significant increase in number of Indian journals indexed in the SCI-E. As shown earlier, more than fifty percent of papers in Indian journals are coming from domestic institutions. Thus, more probability has emerged for papers published by Indian institutions getting reflected in SCI-E journals. Indian government has also given a strong push for improving research publications. This has happened primarily due to public debates triggered by poor ranking of Indian universities globally, India not making a mark in global science, etc. (see for example Times higher education ranking,[5] debate on India not receiving noble prize[6]).

Among the measures taken is mandatory provision for PhD scholars or research interns to publish with emphasis towards IF journals (see for example CSIR guidelines for Research Associates,[7] AcSIR guidelines for PhD Admissions[8]). Indian government has also established dedicated research driven universities called IISER (Indian Institute of Science Education and Research) and created a research academy in the largest chain of public

[5] http://www.timeshighereducation.co.uk/world-university-rankings/2014/reputation-ranking.

[6] https://churumuri.wordpress.com/tag/nobel-prize/; http://www.mapsofindia.com/my-india/india/deserving-indian-scientists-but-deprived-of-nobel-prize.

[7] http://csirhrdg.res.in/jrfsrfra2.htm.

[8] http://acsir.res.in/frequently-asked-questions/.

Table 4 Indian firms actively involved in publishing

Industry	Papers	No. of collaborative institutions [major collaborators (papers)]
2006		
Texas Instruments[a]	17	3 [IIT's (2); Oregon University (2); IISc (1)]
Ogene Systems	16	3 [CSIR (32); University of Tokyo (1); Institute Rech Catalyse (1)]
Laxmi Fumigation Pest Control	15	20 [APS University (13); Bareilly College (4); Holkar Model Autonomous College (4); University of Florence (4)]
GE India Technology Center[a]	11	9 [IITs (2); Nanyang Technological University (2); Oregon University (2)]
Fluent India[a]	6	2 [IIT (6); IISc (1)]
Reliance Life Science	5	14 [John Hopkins University (2); Bresagen (1); Cellartis (1)]
2012		
Astrazeneca India[a]	16	6 [Univ. of Hyderabad (2); Uppsala Univ. (2); Southern Illinois Univ. (2)]
GVK Bioscience	18	Jawaharlal Nehru Technological University (11); Andhra University (2); University of Tokyo (2)
Texas Instruments[a]	15	16 [IITs (8); University of Maryland (4); IISc (2)]
Therachem Research Medilab	12	–
2006		
Heron Health[a]	12	2 [Mayes College Healthcare Business Policy (1); PFIZER (1)]
GM Technology Center[a]	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 Therapeuticals (2)]
Dr. Macs Biopharma	7	5 [JNTU (6); Univ. of Tokyo (4); GVK Biosciences (2)]

Source: SCI-E

– implies no collaboration

[a] Firms primarily their Foreign R&D centers in India

laboratories CSIR (refer Academy of Scientific and Innovative Research[4]). Thus the emergence of new institutions and strong policy directive of Indian government along with substantial increase of Indian journals in the SCI-E database is seen as plausible reasons behind the increase observed in number of institutes involved in publishing activity in the SCI-E. The number of firms involved in publication activity has increased more than 50 % in 2012 from that in 2000 (Table 3). Table 4 further highlights the characteristic of firm's involvement in publication activity.

Table 4 highlights that most of the firms actively involved in publishing activity are multinational entities (primarily their R&D centers in India). One also observes active collaboration with Indian universities and research institutes. This is an interesting development. It shows that two-way knowledge transfer is emerging between foreign R&D centers and Indian entities (Krishna et al. 2012). The relative absence of Indian firms as seen from the above table is a cause for concern. Indian firms publish sporadically and their publications are restricted primarily to life sciences/pharmaceuticals. Lack of Indian industry involvement in research can also be seen from the research investment coming from industry. Higher involvement of Indian industry and networking with universities/research institutes can lead to higher research productivity, and translational research.

(c) *Increase in international collaboration*

Science is becoming increasingly interconnected (see for example Wagner, 2008). International collaboration has shown many positive attributes such as enhancing the impact of research, and bringing together a diversity of skills, funding support, solving complex research problems, etc. (see for example Leydesdorff and Wagner 2008; Archambault 2010; Royal society 2011). International collaboration is also playing a major role in increasing research productivity (see for example Adams 2013). Royal society (2011) highlight developed economies are more involved in collaboration activities. This is particularly high in small advanced economies like Belgium, the Netherlands and Denmark where more than 50 % of research output in 2004–2008 was due to international collaboration. China, Turkey, Taiwan, India, South Korea and Brazil produce over 70 % of their publications from national researchers alone. In case of developing countries like Africa and South-East Asia the international collaborative papers are almost 100 %. These findings are corroborated by Adams (2013). Thus, it is important to see to what extant international collaboration is contributing to the increase of India's research productivity.

As Shrivats and Bhattacharya (2014) has shown that prior to 1995, Indian authors had sporadic international collaboration resulting in only a very insignificant volume in comparison to India's overall publication. The change could be observed from 1995; during the period 1995–2012, the number of internationally collaborated scientific publications as a percentage of overall Indian scientific publications increased from about 11 % to about 20 %. The role of international collaboration in India's overall publication productivity has shifted from a position of little importance to one of significant importance. The results thus show that internationally collaborative papers have played a significant role in the increase of total volume of papers from India. Table 5 provides descriptive statistics for three different time periods to highlight the changes.

The major collaborating partners of India are USA, Japan, Germany, England and France. These five countries contributed 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. India's collaborating pattern however is changing in recent years. Indian researcher's engagement with other BRICKS countries is increasing. In 2012, S. Korea and China has emerged as the fourth and seventh most prolific collaborative partner of India.

Kostoff et al. (2007c) showed that International collaboration has significant impact on increasing the probability of presence of a paper in high impact journal. This study was

Table 5 Internationally collaborative papers from India

	Total papers		Collaborative papers (% share of total papers)		Domestic papers (% share of total papers)	
	SCI-E	Scopus	SCI-E	Scopus	SCI-E	Scopus
2000	19,522	23,676	3206 (16)	4924 (21)	16,316 (84)	18,752 (79)
2006	34,674	45,468	6276 (18)	11,776 (26)	28,398 (82)	33,692 (74)
2012	62,751	99,771	11,588 (18)	26,342 (26)	51,163 (82)	73,429 (74)
GR (2000–2012)	221	321	261	435	214	292

GR Growth rate = $(Y - X/X) * 100$

Table 6 Impact of international collaboration

Journals (Impact Factor)	1987–2005		2005		2006–2012		2012	
	India only (% share*)	Collaborative papers (% share**)	India only (% share*)	Collaborative papers (% share**)	India only (% share*)	Collaborative papers (% share**)	India only (% share*)	Collaborative papers (% share**)
Nature (38.597)	164 (68)	78 (32)	1 (11)	8 (89)	25 (38)	41 (62)	9 (60)	6 (40)
Science (31.027)	34 (35)	64 (65)	2 (20)	8 (80)	29 (30)	67 (70)	6 (43)	8 (57)
Physical Review Letters (7.943)	411 (42)	558 (58)	25 (19)	106 (81)	144 (20)	569 (80)	17 (15)	93 (85)
PNAS-USA (9.737)	106 (62)	65 (38)	13 (59)	9 (41)	172 (58)	124 (42)	36 (56)	28 (44)

* % share of domestic papers from total papers of India; ** % share of collaborative papers from total papers of India

done for four influential journals in 2005. We have further investigated the activity of India in the same four journals for 2012 and for the period 1987–2005 and 2006–2012 to see whether the trend is changing or not (Table 6).

Table 6 *clearly indicates that the role of international collaboration in publication in influential journals. This result shows that what Kostoff* et al. (2007c) *observed in 2005 remains true in the contemporary period. Similar results are also observed regarding Indian papers in Top 1 % highly cited papers globally. In 2000* in the Top 1 % highly cited papers, 65 % of Indian research papers were collaborative while only 35 % non-collaborative papers. Further, majority of these collaborative papers were coming from international collaboration i.e. 53 % while only 12 % from domestic collaboration. Similarly in 2006, 69 % of the Top 1 % highly cited papers are collaborative of which 54 % are internationally collaborative and 15 % coming from domestic collaboration. This trend is again observed in 2012; of the 340 top 1 % highly cited papers in that year, 78 % are collaborative of which 63 % are coming from international collaboration.

(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;[9] for example, nanotechnology, biotechnology, advanced materials, computational and synthetic biology. Grieneisen (2010) has shown the dramatic increase in the number of nanotechnology journals from 1985 to 2010. A similar phenomenon is happening in other emerging research fields. Thus countries which are expanding their scope of research and publishing in emerging research areas have marked positive effect in their publication productivity. Apart from this, it makes an assertion of their scientific capability; entering new promising areas of research where stakes are high and established scientific nations are competing.

Indian researchers are actively publishing in some of the emerging fields/subfields. This is particularly true in nanotechnology, advanced materials and to some extent in biotechnology. This has placed India among the top 15 publishing countries in many of these emerging fields/subfields. In nanotechnology, the publication growth has been very rapid. India has emerged as the 6th most active publishing country in this field (Bhattacharya et al. 2012b). India's overall paper production in nanotechnology was 49,199 during the period 1990–2012. Figure 8 provides further evidence of the influence of emerging fields in India's overall paper productivity.

The figure again demonstrates the positive influence of emerging fields in India's overall growth of papers.

We have so far examined the plausible reasons behind India's publication growth. We also discern some other salient aspects of India's publication activity to inform further the debate i.e. to what extent India is influencing the global landscape of science.

[9] The study identifies emerging research areas (also sometimes called cutting edge research fields) as those fields which are having growing influence globally. Fields of growing influence can be discerned from dedicated programs/roadmaps and strategies and high investments made by different countries (see for example strategies and funding in nanotechnology in different countries in Bhattacharya et al. 2012a). One can see in recent years, this is happening in biotechnology, nanotechnology, computational biology, synthetic biology/genomics, etc. One characteristic of these research fields is their interdisciplinary and their strong interface with technology. Studies have identified the effect of this dedicated support on research productivity. Explosive increase in nanotechnology papers is one example of this (Chen et al. 2013).

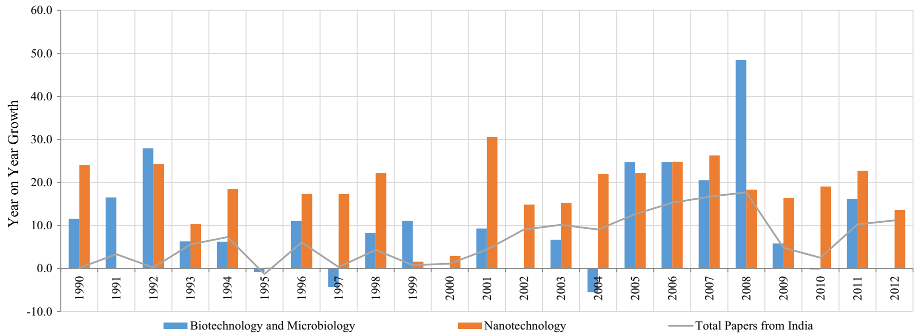

Fig. 8 Year-on-Year Publication Trend: India's Total Publications, and Publications in Nanotechnology and 'Biotechnology & Microbiology'. *Source*: SCI-E; *Note*: For year 1991 the value of increase for nanotechnology is 379 which we have deleted for clarity of figure; Search string for Biotechnology & Microbiology =>Web of science categories; Nanotechnology => Arora et al. 2013; Year on Year Growth => $(X + 1 - X)/X * 100$, X denoting a particular year

Influence of Indian journals

Impact factor (IF) of a journal, to what extent it is an indication of quality, has been a matter of debate (see for example Balaram 2008). Barabási et al. (2012) has shown within the 'Nature' journal itself the citation distribution is highly skewed and do not follow the Gaussian distribution. Only a few papers account for majority of citations and they push the overall impact factor of Nature journal. However, studies have also shown that higher IF journals do play a role in attracting paper visibility (see for example Royal Society 2010). Keeping the above aspects in context, we examine the IF of Indian journals.

As Fig. 7a shows, there is significant increase in number of Indian journals in the SCI-E. Inspite of this positive trend, we find majority of Indian journals are in the low IF range 0.1–3. The maximum IF of Indian journal is 2.722. But statistics do indicate some positive trends. One observes that only one journal had IF ≥ 1 in year 2005 which increased to 17 journals in 2012. To take into account the size effect (normalisation done with the total Indian journals in the JCR), percentage of journals observed with IF ≥ 1 was 2 % and 16 % in 2005 and 2012 respectively. The growth of journals in the JCR was increasing

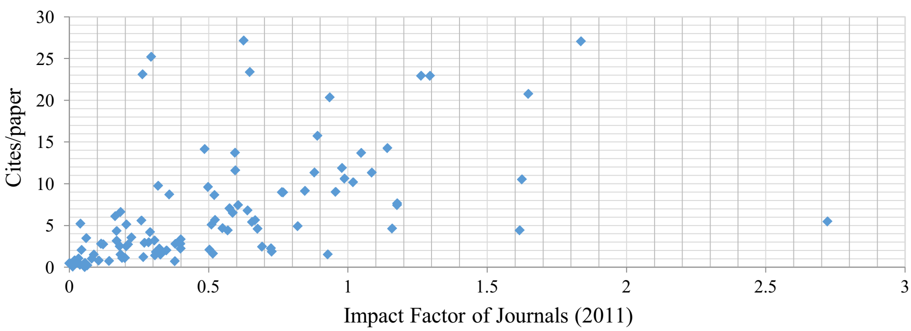

Fig. 9 Citation impact w.r.t. impact factor of Indian journals (2011). *Source*: JCR; *Note*: Citation Impact (Cites per paper) is with respect to the total papers in a journal

rapidly but the corresponding increase of journals with IF $\geq$ 1 was not visible; for example, of the 68 journals indexed in 2009 only 3 journals had IF $\geq$ 1. Only from 2010 we see the change happening, of the 94 journals indexed in 2009, 9 journals had IF $\geq$ 1, of the 99 journals indexed in 2011, 14 journals had IF $\geq$ 1 and in 2012, of the 105 journals indexed 17 journals had IF $\geq$ 1.

We further examine the relationship between citation reception of papers in Indian journals and IF of Indian journals (Fig. 9). The figure looks at aggregated cites-per-paper of Indian journal in the SCI versus IF of a journal. The aggregated picture is given with the caveat of the skewed citation distribution within each journal. To overcome this it becomes an elaborate exercise to examine each journal and count paper-by-paper citations which the present study has not undertaken.

Figure 9 demonstrates that IF is only a crude indicator of Indian journal influence. Average cites-per-paper of some low IF journals are very high and vice versa. This may be due to a few highly cited papers in a low IF journal. The correlation between IF and cites-per-paper is 0.51; this accounts for 25 % of variance. There is differing opinion of interpretations but as a conservative estimate one can say that there is some degree of association between IF of Indian journals and citations received by their papers.[10] This distribution may vary with the subject field which has not been analysed here.

Indian papers: global influence

Observing the citation reception of Indian papers, a ‘proxy’ judgment can be made of whether influence of Indian papers is increasing or otherwise. We examined this through (a) The papers receiving at-least one citation over a 3 and 5 years period; (b) papers in Global Top 1 % and Top 100 highly cited papers; (c) papers in high impact journals. The SCI-E covered 51,177 Indian publications in 2010 of which 16,116 papers (31 % of total papers) remained uncited (taking 3 years 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 5 years citation window) [refer Footnote 11 for rationale behind taking different citation window].[11] 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 7 examines Indian papers global reception in comparison with other BRICKS countries.

Adams et al. (2013)analysed the presence of BRICK countries in globally top 1 % highly cited papers from year 2002–2011. They showed that China and S. Korea have significantly increased their presence in later years while Brazil, India and Russia are still farther. Our analysis further qualifies this picture. Among BRICKS countries, China has not only increased volume substantially but her 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 63 papers in the Top 1 % cited papers whereas in 2006 her

[10] Some authors like Field (2005) consider values above 0.5 as large effect.

[11] Citations accumulate over time and thus older papers have, on average, more citations than more recent papers. Therefore fixed citation window is taken when comparison of citation reception in two different periods is undertaken ensuring that no bias is given for papers in any particular period. However, in this study two different citation windows were taken to show that papers in 2010 are receiving reception faster inspite of longer citation window for 2008.

Table 7 Highly cited papers from BRICKS countries

	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)
Brazil	12,985 (17)	1 (19)	31 (27)	22,263 (16)	1 (27)	116 (21)	41,821 (13)	7 (21)	252 (24)
Russia	28,069 (9)	3 (12)	78 (20)	26,037 (14)	2 (17)	115 (20)	29,877 (16)	11 (15)	235 (26)
India	18,168 (13)	1 (19)	63 (23)	31,109 (12)	2 (17)	127 (23)	53,523 (12)	6 (26)	326 (20)
China	31,059 (8)	1 (19)	115 (18)	91,449 (4)	2 (17)	573 (7)	194,225 (2)	22 (4)	2,287 (4)
S. Korea	15,117 (16)	1 (19)	65 (21)	32,672 (11)	1 (27)	188 (17)	54,968 (10)	14 (13)	564 (13)
S. Africa	4,008 (35)	–	25 (31)	5,724 (37)	1 (27)	72 (28)	9,933 (34)	5 (32)	136 (35)

Source: SCI-E

* Number of papers present in Top 100 highly cited papers (HCP) from respective country; ** Number of papers present in Top 1 % HCP from respective country; Accessed on 14 March 2014

Table 8 Indian publications in high impact journals in different areas (2012)

Journal (IF)	Area (SJR rank in respective area)	Total papers		Papers from India		Collaborative papers			
						International (collaborating countries)		Domestic	
		2012	2006	2012	2006	2012	2006	2012	2006
Cancer Journal for Clinicians (153.459)	Medicine (1)	37	42	–	–	–	–	–	–
Chemical Reviews (41.298)	Chemistry (1)	183	198	9	2	6 (32)	–	2	–
LANCET (39.06)	Medicine (16)	1826	1820	44	49	22 (47)	16 (40)	4	5
Nature Materials (35.749)	Engineering (1)	288	301	–	1	–	1 (1)	–	–
Nature Reviews Genetics (41.063)	Agriculture & Biosciences (1)	158	212	–	1	–	–	–	–
Nature (38.597)	Multidisciplinary (1)	2651	2733	15	9	6 (34)	4 (5)	1	–
The New England Journal of Medicine (51.658)	Medicine (5)	1617	1785	16	12	12 (38)	1 (3)	2	–
Reviews of Modern Physics (44.982)	Physics & Astronomy (1)	46	34	1	–	1 (1)	–	–	–
IEEE Transactions on Pattern Analysis & Machine Intelligence (4.8)	Computer Science (1)	196	189	1	1	–	–	1	–
Annual Review of Biochemistry (27.681)	Biochemistry (1)	32	30	–	–	–	–	–	–
Advances in Physics (34.294)	Material Sciences (1)	7	12	–	–	–	–	–	–
Annals of Statistics (2.53)	Mathematics (1)	118	120	–	–	–	–	–	–
Science (31.027)	Multidisciplinary (2)	2388	2374	14	13	7 (47)	9 (23)	2	2

Source: SCImago

Rank is based on SCImago Journal Rank (SJR) indicator (Refer Footnote 12 for details)

contribution was 127, and in 2012 was 326. India's increase in research volume do not commensurate with citation reception; it is now among the top ten countries in research papers but is far below when ranked in highly cited papers. Same is the case of other BRICKS countries. *Thus, we can conclude that although BRICKS countries have significantly increased the number of papers in highly cited papers but when compared with advanced OECD countries the influence of their papers is significantly low*. Inspite of increase in research volume (in terms of publications) of BRICKS countries, the traditionally scientifically advanced countries still attract majority of citations (high influence).

Table 9 Prolific journals containing most papers by Indian authors (2012)

Journal title (IF)	Area (rank in respective area)	Papers	Country
PLOS ONE (4.092)	Multidisciplinary (308)	530	US
Current Science (0.905)	Multidisciplinary (26)	529	India
Tetrahedron Letters (2.683)	Chemistry (501)	396	UK
Spectrochimica Acta Part A Molecular and Biomolecular Spectroscopy (2.098)	Chemistry (329)	377	Netherlands
Asian Journal of Chemistry (0.266)	Chemistry (693)	324	India
Journal of Applied Physics (2.168)	Physics and Astronomy (49)	271	US
Medicinal Chemistry Research (1.271)	Chemistry (475)	261	US
Physical Review D (4.558)	Physics and Astronomy (64)	257	US
Indian Journal of Medical Research (1.837)	Medicine (1109)	256	India
RSC Advances (2.562)	Chemical Engineering (133)	256	UK

Rank is based on SCImago Journal Rank (SJR) indicator developed by SCImago (Bote and Anegon 2012)

Examination of Top 1 % highly cited papers in 2012 show that developed countries like the USA accounted for 53 % of these highly cited papers, Germany 15 %, and UK 14 %.

Table 8 shows the presence of Indian papers in high impact journals (HIJ).

The Table 8 shows Indian authors negligible presence in HIJ. HIJ are top journals in each field (SJR rank) and to some extent overcomes the biases that happens when activity is observed through IF of a journal as it does not take into consideration the wide differences in citation practice across disciplines.[12] The Table 8 also includes some journal which are not leaders in their field as per SJR rank but nevertheless have high global influence. The findings also show that many of the papers in HIJ is coming from International collaboration. Thus although India's publication is increasing exponentially but its visibility in high impact journals is lacking. Publications in journals highly rated in a discipline do indicate that research is of high relevance to that community and the paper has met the stringent criterions that top journals require papers to meet for publishing in them. *The result may be due to Indian authors not targeting HIJ for publishing or the submitted papers in the high impact journals are getting rejected and maybe then authors are submitting those papers again in low impact journals.* It is not possible to discover this statistics. Table 9 exhibits top ten most preferred journals by Indian authors.

Table 8 highlights that Indian authors are publishing in journals which are not high in ranking in their field. This result complements finding from Table 9. But there are other salient facts emerging from the above table. Among the top five prolific journals, only two

[12] SJR is a size independent indicator which gives the measure of relative journal's standing. It takes into account the citations of the journal and the closeness of cited journal using the cosine of the angle between the vectors of the co-citing journals. This quantity is then divided by the fraction of journals citable documents to reduce the effect of size. Bote and Anegon (2012) thus argue that SJR is better measure than other ranking measures like JIF because SJR is more equally distributed in different subject areas and the inclusion of cosine reduces the chances of changed journal standing in closely related areas like Chemistry and Biochemistry.

journals are from India. Inspite of increase of Indian journals in the SCI-E (Fig. 7a), only 11 journals in the 25 most preferred journals are domestic journals. Indian researchers are also publishing in higher IF journals, 17 of the top 25 preferred journals have IF greater than one. The positive change can be observed when we compare our results with from the findings from similar analysis done by Kostoff et al. (2007c) for the year 2005. Their study showed that 15 of the Top 25 journals were domestic journals, and only in 8 of the overall 25 preferred journals had IF greater than one. Thus, it can be seen that *Indian authors are expanding their publication scope, a positive trend;* motivation may be to publish in high impact journals which can also be seen from the result. Al*though the citation impact of Indian papers is still less (Table 7), and presence of Indian papers is still insignificant in HIJ (Tables 6, 8 and 9) but when one compares with publication activity in earlier time-period, the growth is seen not only in terms of volume but also in quality (examining through the proxy indicators based on citation), addressing new research areas among others.*

Conclusions

The study claims that the global publication landscape is changing with emerging economies especially China playing a major role behind this change. It thus supports evidence coming from number of recent studies that point in this direction. The study informs this debate further. Results indicate that only in comparison to China, the other BRICKS countries seem to underperform. But the fact is that the publication growth is impressive especially for India and South Korea. Results also highlight that statistically there is no significant difference between the publication profile of advanced OECD countries and BRICKS. Publication share of advanced OECD countries is decreasing whereas of BRICKS countries increasing. Thus, the study posits that this can lead to significant shift of global research activity. However, the publication activity of Non-OECD countries are highly skewed with only a few countries accounting for the overall publication shown by this group of countries. This is unlike that of OECD countries where the publication activity is more uniformly distributed. Thus, one hand we observe higher engagement of a few SOUTH economies in publication activity but on the other hand increasing SOUTH–SOUTH gap is observed.

The changing contour of global landscape was examined in more depth by examing the publication activity of India. Rapid rise in publication is observed from 2000 onwards. The study identifies four major reasons behind this growth *(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. Section below highlights the above four findings in more details.* The increase in journals in the two databases i.e. SCI-E and the Scopus (roughly an increase of approximately 120 % in journal coverage in these two databases from 2000 to 2012) provides more opportunity for Indian researchers to have their publications reflected through these two databases. Particularly the greater number of Indian journals indexed in these two databases plays an influential role in India's publication growth as the 'home advantage' phenomenon. Other factors that are contributing to the growth are involvement of more institutes in publishing activity and increase in international collaboration. In emerging areas, India is visible among the top publishing countries which is also driving her publication growth.

The increase in volume (research papers) does not commensurate with India's citation profile. Indian papers visibility in highly cited papers, citations per paper and in high impact journals are low. However, when one compares India's citation profile with earlier time-period, the trend is positive. Indian researchers are publishing more actively in higher impact factor journals now, and journals in which their majority of research is visible is not restricted to Indian journals as unlike the earlier periods. 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.

Indian research activity compares well with BRICKS and other advanced scientific countries. China has made the major influence among BRICKS countries and now in the top league in publication volume and also her papers are getting more global visibility. India also has emerged as an important player, her progress not really as remarkable like China, nevertheless a very healthy positive trend. Indian publications are visible in cutting-edge science based technology areas.

Some major policy implications emerge from this study. The emergence of some SOUTH countries in the global publication landscape indicates new research hot-spots are emerging globally. More informed policy inputs emerge from the detail investigation of Indian research productivity. Relative comparison with different countries supports the argument of the need for India to devote higher investment in R&D. International collaboration is an important factor in increasing volume and influence. More opportunities need to be created at the institutional level to promote international collaboration. Indian firms need to be more active in research (publication activity is a good reflection of research activity) and engage more actively with Indian institutions. Particularly in cutting-edge research areas there is a need for academia-industry linkage (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 or high impact journals in a field/subfield is one indication of this). This would lead to higher visibility of Indian research activity. Indian journals have low global impact and more efforts are required such as strengthening peer review system, editorial policies, timeliness of journal publication for attracting high quality research papers. Only a few institutes account for majority of research publications. More efforts are required to correct this imbalance.

Further research is required to show how the research networks and knowledge links are developing between different countries. A series of recent studies have examined this issue. But further evidence based research will help to inform the policy makers and enrich scholarly debate.

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References

Adams, J. (2012). Collaborations: The rise of research networks. *Nature, 490*, 335–336.

Adams, J. (2013). Collaborations: The fourth age of research. *Nature, 497*(7451), 557–560.

Adams, J., Pendlebury, D., & Stembridge, B. (2013). *Building BRICKs exploring the global research and innovation impact of Brazil, Russia, India, China and South Korea*. New York: Thomson Reuters.

Agtmael, A. V. (2007). *The emerging markets century: How a new breed of world class companies is overtaking the world*. New York: Free Press.

Archambault, E. (2010). *30 years in science: Secular movements in knowledge creation*. Montréal: Science-Metrix.
Arora, S. K., Porter, A. L., Youtie, J., & Shapira, P. (2013). Capturing new developments in an emerging technology: an updated search strategy for identifying nanotechnology research outputs. *Scientometrics, 95*, 351–370.
Balaram, P. (2008). Scientometrics: A dismal science. *Current Science, 95*(4), 431–432.
Barabási, A. L., Song, C., & Wang, D. (2012). Publishing: Handful of papers dominates citation. *Nature, 40*, 491.
Basu, A. (1999). Science publication indicators for India: Questions of interpretation. *Scientometrics, 44*(3), 347–360.
Bettelle, Rdmag (2012). *Global R&D funding forecast.* Battelle and R&D. (www.battelle.org, www.rdmag.com).
Bettelle, Rdmag (2013). *Global R&D funding forecast*. Battelle and R&D. (www.battelle.org, www.rdmag.com).
Bhattacharya, S., Shilpa, & Bhati, M. (2012a). China and India: The two new players in nanotechnology race. *Scientometrics, 93*(1), 59–87. doi:10.1007/s11192-012-01651-7.
Bhattacharya, S., Jayanthi, A. P., Shilpa, & Bhati, M. (2012b). *Knowledge creation and innovation in nanotechnology: Contemporary and emerging scenario in India*. Prepared by National Institute of Science Technology and Development Studies. (website link—http://www.nistads.res.in/ under reports).
Bote, V. P. G., & Anegon, F. M. (2012). A further step forward in measuring journals' scientific prestige: The SJR2 indicator. *Journal of Informetrics, 6*, 674–688.
Bound, K. (2007). *India: The uneven innovator*. The Atlas of ideas: Mapping the new geography of science (www.demos.co.uk). London: The Good News Press.
Bound, K. (2008). *Brazil the natural knowledge economy*. The Atlas of ideas: Mapping the new geography of science (www.demos.co.uk). London: The Good News Press.
Chen, H., Roco, M. C., Son, J., Jiang, S., Larson, C. A., & Gao, Q. (2013). Global nanotechnology development from 1991 to 2012: patents, scientific publications, and effect of NSF funding. *Scientometrics, 15*(1951), 1–21.
Dolfsma, W. (2008). *Knowledge economies—Innovation, organization and location*. Routledge Studies in Global Competetion. London and New York: Taylor & Francis.
Doz, Y., Wilson, K., Veldhoen, S., Goldbrunner, T., & Altmann, G. (2006). *Innovation: Is global the way forward?* A joint study by Booz & Company and INSEAD Survey Results. (pp. 1–13). Fontainebleu France & McLean, Virginia: INSEAD and Booz Allen Hamilton.
Elsevier, B.V. (2012). *Bibliometric study of India's scientific publication outputs during 2001–2010*. Study commissioned by Department of Science and Technology—NSTMIS, India.
Evidence. (2011). *A bibliometric study of India's research output and collaboration.* Study commissioned by Department of Science and Technology—NSTMIS, India. (website: http://dst.gov.in/whats_new/whats_new12/report.pdf).
Field, A. (2005). *Discovering statistics using SPSS* (2nd ed.). Chapter seven: Comparing two means. London: Sage publications.
Gibbons, M., Limoges, C., Nowotny, H., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (1994). *The new production of knowledge-The dynamics of science and research in contemporary societies*. CA: Sage Publications Ltd.
Glanzel, W., Debackere, K., & Meyer, M. (2008). 'Triad'or 'tetrad'? On global changes in a dynamic world. *Scientometrics, 74*(1), 71–88.
Grieneisen, M. L. (2010). The prolifereation of nano journals. *Nature nanotechnology*, *5*, 825.
Hassan, M. H. A. (2005). Small things and big changes in the developing world. *Science, 309*(5731), 65–66.
Huggins, R., & Izushi, H. (2007). *Competing for knowledge: Creating, connecting, and growing*. London and New York: Routledge and Taylor & Francis.
Kostoff, R. N., Briggs, M. B., Rushenberg, R. L., Bowles, C. A., Icenhour, A. S., Nikodym, K. F., et al. (2007a). Chinese science and technology—Structure and infrastructure. *Technological Forecasting and Social Change, 74*(9), 1539–1573.
Kostoff, R. N., Briggs, M. B., Rushenberg, R. L., Bowles, C. A., Pecht, M., Johnson, D., et al. (2007b). Comparisons of the structure and infrastructure of Chinese and Indian science and technology. *Technological Forecasting and Social Change, 74*(9), 1609–1630.
Kostoff, R. N., Johnson, D., Bowles, C. A., Bhattacharya, S., Icenhour, A. S., Nikodym, K., et al. (2007c). Assessment of India's literature. *Technological Forecasting and Social Change, 74*, 1574–1608.
Krishna, V. V., Patra, S. K., & Bhattacharya, S. (2012). Internationalization of R&D and global nature of innovation: Emerging trends in India. *Science Technology & Society, 17*(2), 165–199.

Leydesdorff, L., & Wagner, C. (2008). International collaboration in science and the formation of a core group. *Journal of Informetrics, 2*(4), 317–325.

Leydesdorff, L., & Wagner, C. (2009). Is the United States losing ground in science? A global perspective on the world science system. *Scientometrics, 78*(1), 23–36.

Moiwo, J. P., & Tao, F. (2013). The changing dynamics in citation index publication position China in a race with the USA for global leadership. *Scientometrics, 95*(3), 1031–1050.

Montgomery, P. H. (1999). Promises and threats of knowledge-based economy. *Nature, 397*(6714), 1–88. Editorial.

Organisation for Economic Co-operation and Development. (1996). *The Knowledge-based economy*. Paris: OECD.

Panat, R. (2014). On the data and analysis of research output of India and China: India has significantly fallen behind China. *Scientometrics, 100*(2), 471–481. doi:10.1007/s11192-014-1236-4.

Raghuram, N., & Madhavi, Y. (1996). India's declining ranking. *Nature, 383*, 572.

Rosenthal, R. (1991). *Meta-analytic procedures for social research (Revised)*. Newbury Park, CA: Sage.

Rosnow, R. L., & Rosenthal, R. (2005). *Beginning behavioral research: A Conceptual Primer* (5th ed.). Englewood Cliffs, NJ: Pearson/Prentice Hall.

Royal Society. (2010). *The Scientific century: Securing our future prosperity*. UK: Royal Society Publishing.

Royal Society. (2011). *Knowledge, network and nations*. UK: Royal Society Publishing.

Sandhya, G.D., Nath, P., Mrinalini, N., Bannerji, P., Bhattacharya, S., Mandal, K. (2013). *A comparative study on S&T, innovation and development strategies of China and Korea vis-à-vis India'*, Study commissioned by the Office of the Principal Scientific Advisor, Government of India, to CSIR-National Institute of Science Technology and Development Studies.

Shrivats, S. V., & Bhattacharya, S. (2014). Forecasting the trend of international scientific collaboration. *Scientometrics, 101*(3), 1941–1954. doi:10.1007/s11192-014-1364-x.

Sveiby, K. E. (1997). *The new organizational wealth: Managing and measuring knowledge-based assets* (1st ed.). San Francisco: Berrett-Koehler Publishers.

United Nations Educational, Scientific and Cultural Organization (UNESCO). (2010). *The current status of science around the world*. Belgium: DB Print.

US National Academy of Sciences, National Academy of Engineering and Institute of Medicine. (2005). *Rising above the gathering storm: Emerging and employing America for a brighter economic future*. Washington, DC: The National Academies press.

Wagner, C. S. (2008). *The new invisible college*. Washington, DC: Brookings Press.

Wilsdon, J., & Keeley, J. (2007). *China: The next science superpower?* The Atlas of ideas: Mapping the new geography of science (www.demos.co.uk). London: The Good News Press.

Winning, A. (2014). *The research and innovation performance of the G20 and its impact on decisions made by the world's most influential economic leaders*. New York: Thomson Reuters.