Where we stand? A scientometric mapping of Indian Science & Technology research in some major research areas

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Abstract

Contribution of research output in the field of Science & Technology by Indian researchers covered in Web of Science database is compared with other most productive countries for different research areas. This paper analyses the research activity of Indian scientists in terms of total number of publication, global share, share of international collaborative publications and visibility & citation impact for the period 2009-2014. The trend of research output in key research areas clearly indicates that all productive countries have their own strength and weaknesses in different research areas. India is steadily emerging as a potential contender in science & technology research in major research areas. Also South Korea, Taiwan and Iran from Asia subcontinent are progressing and they are among twelve most productive countries in some of the key research areas considered in this paper.

Conference Topic

Mapping and Visualization

Introduction

The output and trend of science & technology (S&T) research in India are of considerable interest to scientometricians from all over the world for quite some time. Arunachalam (2002) and others (Garg, Dutt & Kumar, 2006) have thrown light on Indian S&T research for different periods. Glänzel and Gupta (2008) have analysed S&T research output of India during 1991-2006 and compared the same with other countries. Country wise and research area wise studies have been done by different groups. Aksnes (2010) has studied the research output of Norway in Physics research area. In Indian context, works by different groups on different subject areas are worth mentioning. Chemical Sciences by Gunasekaran, Batcha & Sivaraman (2006), Physics by Gupta & Dhawan (2009), Cosmology by Dutta & Rath (2013), Nanotechnology by Nazim & Ahmad (2008) are few of them. Ranking and status of different countries in the context of global scientific scenario have been studied by Braun, Glänzel & Grupp (1995) and others (Gupta & Dhawan, 2009, Kademani et. al, 2007). It is interesting to see that few countries have made considerable progress in some research areas although their ranking is not good if cumulative output is considered taking all research fields. Development of a country in the field of S&T is closely related with economic growth of that country. As predicted by O'Neil (2005), Indian economy is growing and that is reflected in the scientific output for the last few years. Research fellowships have been increased substantially in the recent past to attract bright researchers and boost S&T research in India. More IISERs (Indian Institute of Science Education & Research) and AIIMSs (All India Institute of Medical Science), NITs (National Institute of Technology) and other S&T research organisations are being set up to increase the research output of India. Global landscape of research in S&T is changing rapidly. China has improved considerably in terms of number of publication for the last six years. India and South Korea are also progressing steadily in terms of number of publication and global share. Taiwan and Iran from Asia are emerging as the competitor to

European countries at least in some research areas during 2009-2014. India stands at 10th position with 2.252% global share and 351,030 numbers of publications during 2009-2014. USA holds the first position with global share of 26.110% followed by Peoples Republic of China (China) with global share of 13.849%. But when we analyse the data according to individual research areas as defined in Web of Science (WoS) of Thomson Reuters we get interesting results. We see that highly productive countries are not doing uniformly in all research areas. In other way we can say that some countries have made remarkable progress in certain research areas.

Objective

The objective of this study is to see the research trend, dynamics and global ranking of countries in individual research areas. We have considered first seven major research areas as defined in WoS in which maximum number of papers has been published during 2009-2014.

Methodology

Data sources and processing

All bibliometric data have been extracted from WoS Core Collection of Thomson Reuters. The period for publication activity has been taken for six years (2009-2014) as findings till 2008 are available in literature. Unless and otherwise mentioned in the text, this time period is considered uniformly. For citation analysis we have considered items published during 2009-2012 for all types of publications covered in WoS. Publications assigned to countries are determined by analysing the total publications available in WoS country wise. For collaboration between India and other countries we have analysed the total publications assigned to India. The research areas considered here are Engineering (14.126%), Chemistry (9.355%), Physics (8.503), Materials Science (6.655%), Computer Science (5.807%), Neurosciences Neurology (4.590%) and Biochemistry Molecular Biology (4.520%) that covers more than 50% of total publications when considered separately during this period. It is worth mentioning here that these research areas are not mutually exclusive as some sub-domains are overlapped. The total number of publications is 4,688,504 (i.e. 43.433% of total publications) when we consider these seven research fields together so that all overlapping fields are mutually excluded. Overlapped data are not manually excluded for these major domains for simplicity. These areas broadly cover one in engineering, two in applied sciences (Materials Science and Computer Science), two in basic sciences (Chemistry and Physics) and two in Medical and Biosciences (Neurosciences Neurology and Biochemistry Molecular Biology). Interestingly, these research fields represent almost all major branches of science & technology. We have considered the research output of twelve most productive countries (as per the data of 2014) for each research area separately. We see that USA and China are far ahead of other productive countries as per the research output is concerned in these fields. In our study we have compared research output of USA with that of China and research outputs of remaining ten countries are compared separately for each research area.

Results and Discussions

Global picture

Total number of publication during 2009-2014 as covered in WoS is 10,794,863. We see a steady growth in terms of number of publication during 2011-2013 and maximum number of papers has been published in the year 2013 (1,953,960). But it is surprising to note that there is a sharp decline in number of publication in 2014 (1,642,661) as per the data available in WoS as on January 14, 2015. This sharp decline (17.72%) is of course a major concern that

may be studied separately. Research trend of productive countries in respect of global share in seven major research areas is discussed in the following sub-sections.

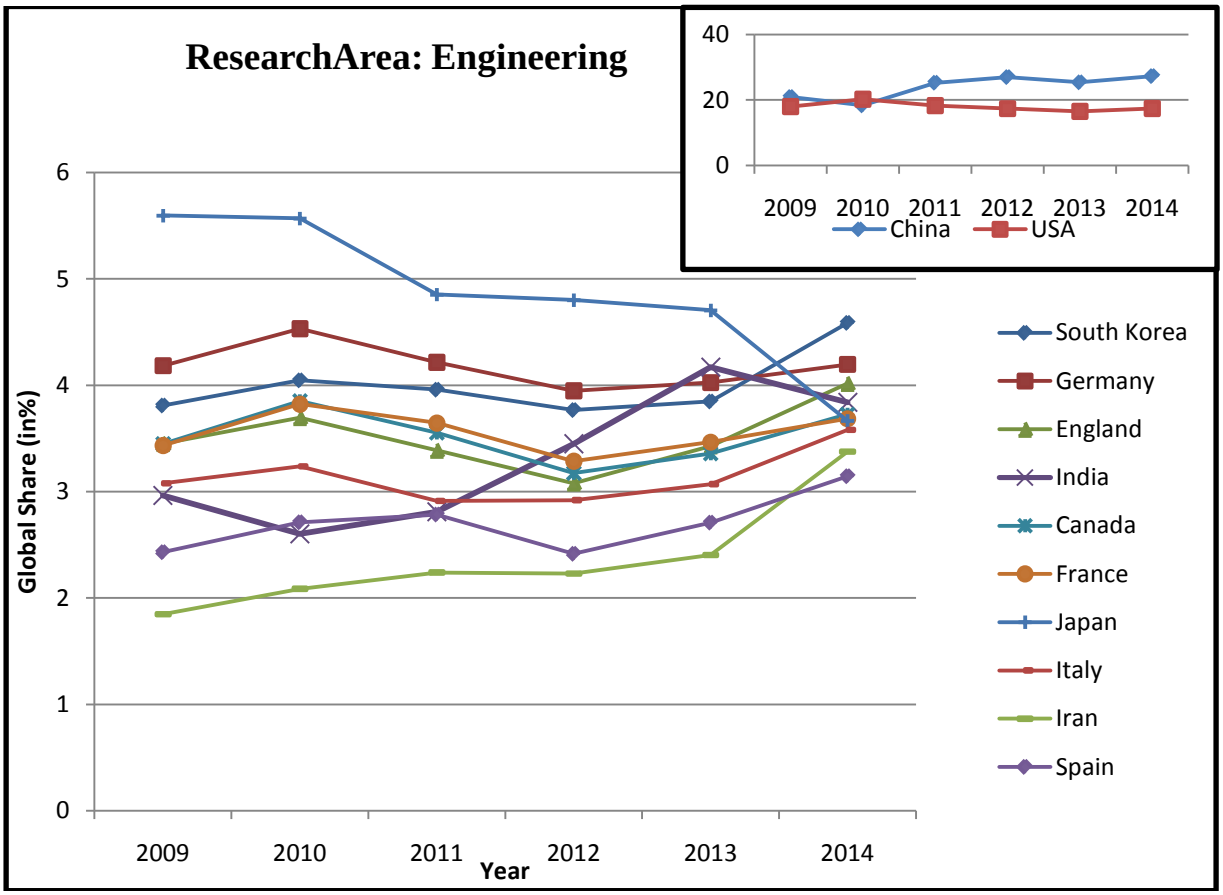

Figure 1. Global share of twelve most productive countries in Engineering research area

Research Area: Engineering

During the period 2009-2014, maximum number (1,521,920) of papers has been published in Engineering research domain. China is number one with a global share of 23.862% followed by USA with global share of 17.926% and India is at 9th position with global share of 3.287%. After analysing the data year wise we see that in 2013 India's research output in Engineering was best (4th) followed by China, USA and Japan with global share of 4.172%. India has improved its position considerably in engineering research during 2012 to 2014 after a slight decrease during the period 2010-2011. In Figure 1 global share of Engineering research output of twelve most productive countries has been shown for the period 2009-2014. From Figure 1 it is interesting to see that global share of Japan has been decreased continuously from 2009 to 2014 and its position in global ranking has been fallen from 3rd position (5.597%) in 2009 to 9th position (3.664%) in 2014. In engineering research, South Korea has made remarkable progress during this period and it has acquired the 3rd position in 2014 in respect of global ranking. Research output of Iran in this field is worth mentioning as global share of Iran has been increased steadily and surpassed Spain in 2014. Other countries (Germany, England, France, Canada, Italy) shown in this Figure are well known in Engineering research for quite some time and they are competitor to each other in this research area.

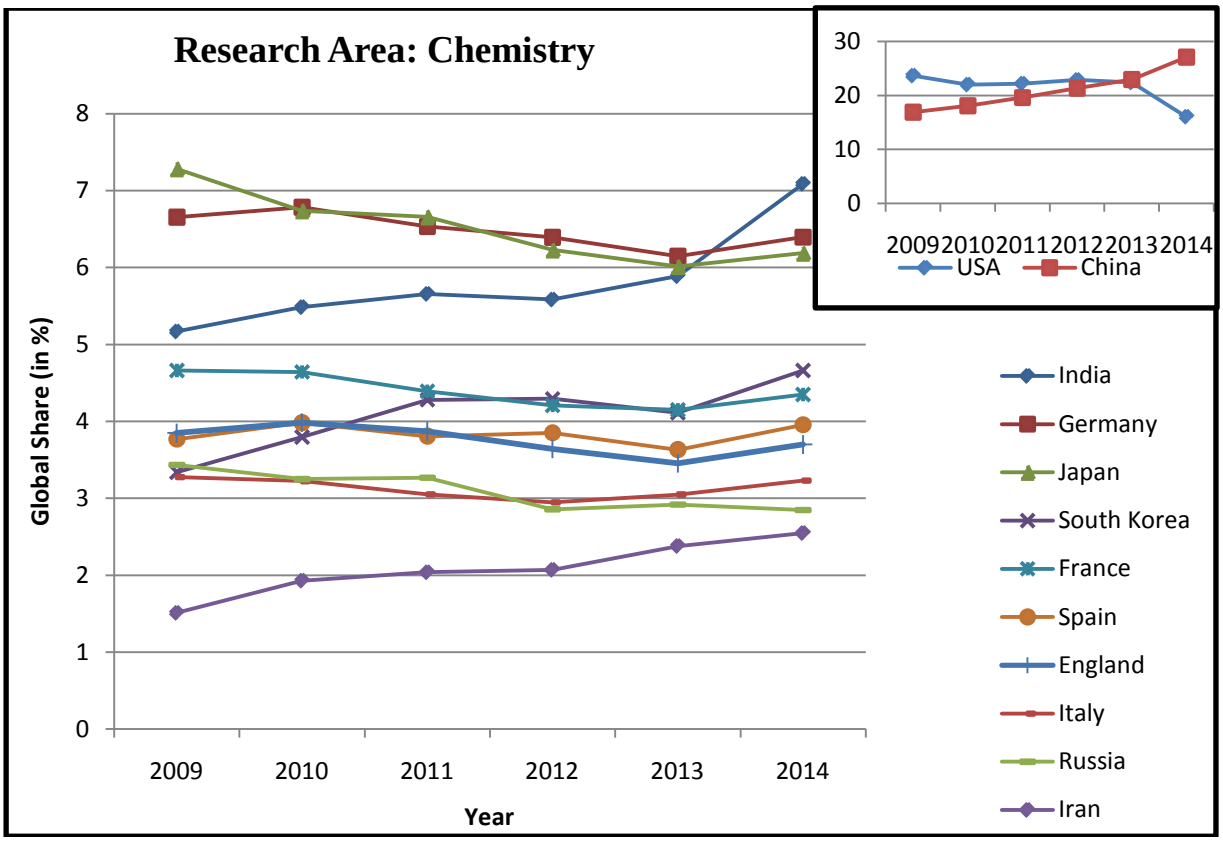

Figure 2. Global share of twelve most productive countries in Chemistry research area

Research Area: Chemistry

The next major research field is Chemistry and a total 1,010,240 number of papers has been published in this research area during the period 2009-2014. USA and China are leaders in this field also in terms of number of publications with global share of 21.566% and 21.099% respectively. India is at 5th position with global share of 5.828%. Chemistry research output of twelve most productive countries in terms of global share has been shown in Figure 2 during 2009-2014. From Figure 2 year wise research output in terms of global share in Chemistry field shows that India stands on a firm position during this period and acquired 3rd position in 2014 followed by USA and China, with global share of 7.088%. India has published maximum number of research papers in Chemistry compared to other research areas and its global share in Chemistry research has been increased steadily during 2009 to 2014. It is evident from Figure 2 that global share of Japan has been decreased from 2009 to 2014 similar to Engineering field as shown in Figure 1 and its positions in global ranking have been fallen from 3rd position (7.284%) in 2009 to 5th position (6.187%) in 2014. Although global share of Germany in Chemistry research has been decreased slightly during this period but Germany has managed to keep its position at 4th during the entire period. South Korea has made notable progress in Chemistry research also during this period and it has improved its position from 10th (3.338%) in 2009 to 6th (4.643%) in 2014 in respect of global share. Iran has increased its research output in Chemistry steadily in terms of global share during this period and in 2014 Iran is just behind Russia at 12th position. Research output of other European countries (France, England, Spain, Italy) shown in this Figure are comparable to each other in this research area and they are placed in between 7th to 10th positions during this period.

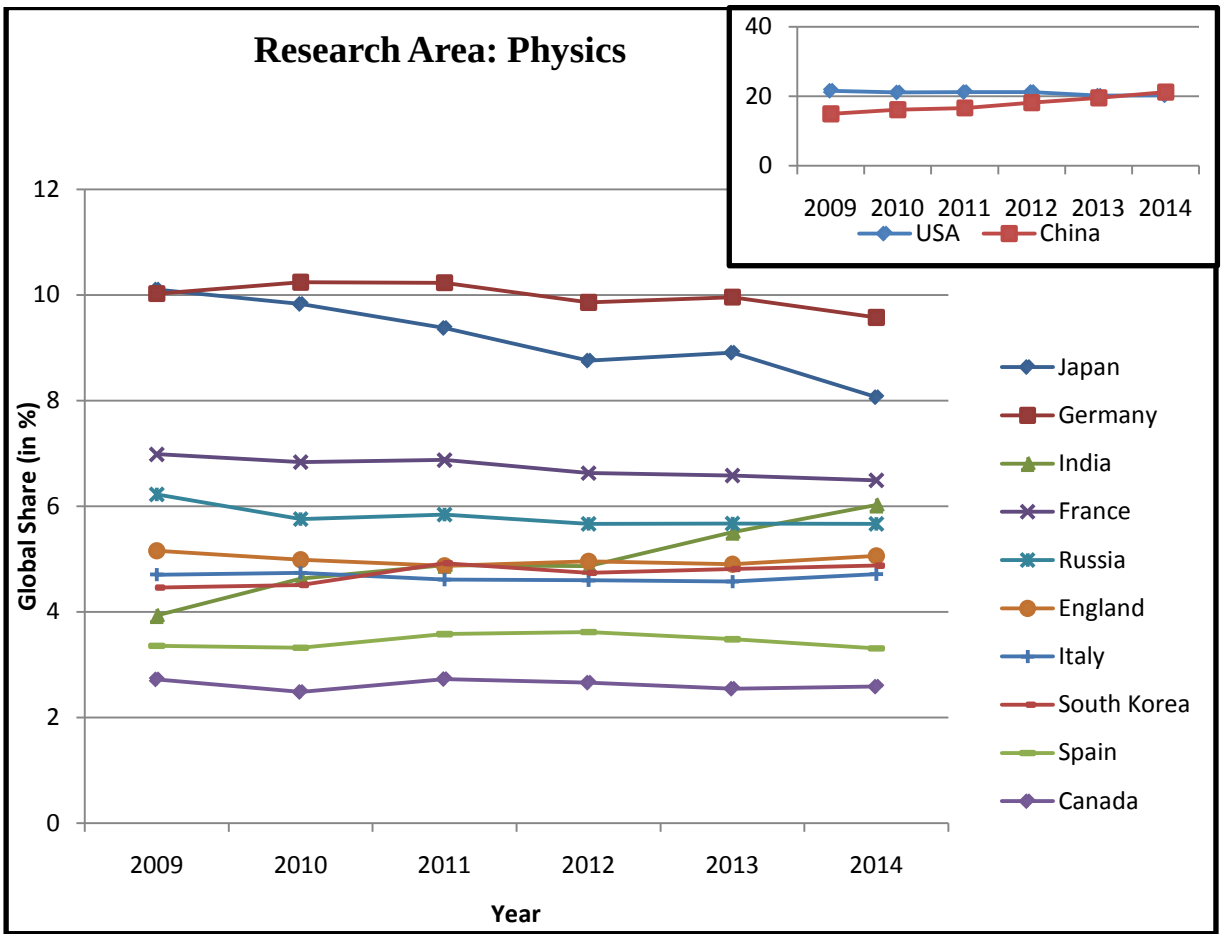

Figure 3. Global share of twelve most productive countries in Physics research area

Research Area: Physics

In terms of total number of publications in a particular research area, Physics is at 3rd position with a total number of publications of 914,073 during the period 2009-2014. USA and China are at top two positions in this field in terms of number of publications with global share of 20.990% and 17.725% respectively. India is at 8th position with global share of 4.960%. In Figure 3 we have shown Physics research output of twelve most productive countries in terms of global share during 2009-2014. Year wise global share in Physics field shows that China has increased its global share continuously during this period and even surpassed USA to acquire 1st position in 2014 whereas global share of USA has been decreased slowly during this period. Germany and Japan are at 3rd and 4th position in terms of global share in Physics research but their global share have been decreased continuously during this period. India's growth in terms of global share is remarkable in Physics and it has improved its position gradually from 10th (2009) to 6th (2014) surpassing traditionally established countries like Russia, England and Italy as shown in Figure 3. France is at 5th position during the entire period of 2009-2014. South Korea has made slight progress in Physics research during this period in terms of global share. Spain and Canada are at 11th and 12th position respectively with almost a constant global share of 3.44% and 2.62% respectively during this period as shown in this Figure.

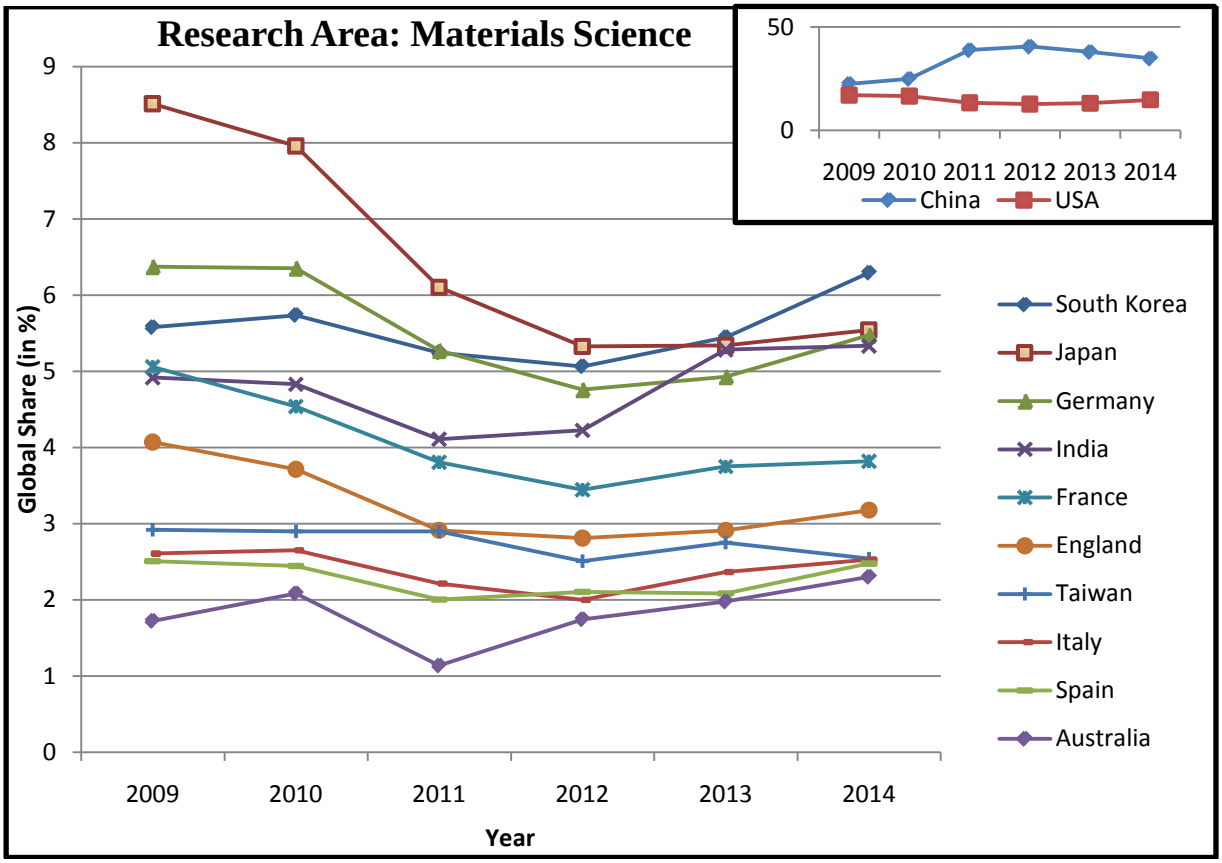

Figure 4. Global share of twelve most productive countries in Materials Science research area

Research Area: Materials Science

Materials Science research is getting popularity amongst scientists during the last few years and a total 717,210 number of articles have been published in this field during 2009-2014 that covers 6.660% of global share. In this field of research, China's growth is outstanding in terms of global share (34.118%) whereas USA is at 2nd position with only 14.271% global share. India is at 6th position (4.768%) followed by Japan (6.285%), South Korea (5.535%) and Germany (5.455%). In Figure 4 research output of twelve most productive countries in Materials Science are compared in terms of global share during 2009-2014. Year wise research output in Materials Science shows that global share of China has almost been doubled during 2009 (22.396%) to 2012 (40.483%) and then decreased during 2013-2014. Global share of USA has been decreased slightly during this period. Japan's contribution in terms of global share has been decreased sharply during this period and in 2014 it falls to 4th position behind South Korea. India's growth in terms of global share is very promising in Materials Science and in 2014 its global share is comparable with that of Germany and Japan. From Figure 4 it is clear that there is tough competition between South Korea, Japan, Germany and India in Materials Science research as per the global share of publication in this research field is concerned. Global share of other potential countries like France, England, Italy and Spain has been decreased during this period as evident from the Figure 4. Taiwan has made remarkable progress in Materials Science research and surpassed Italy and Spain as

shown in Figure 4. Australia is at 12th position in this research area but its global share has been increased during this period as shown in this Figure.

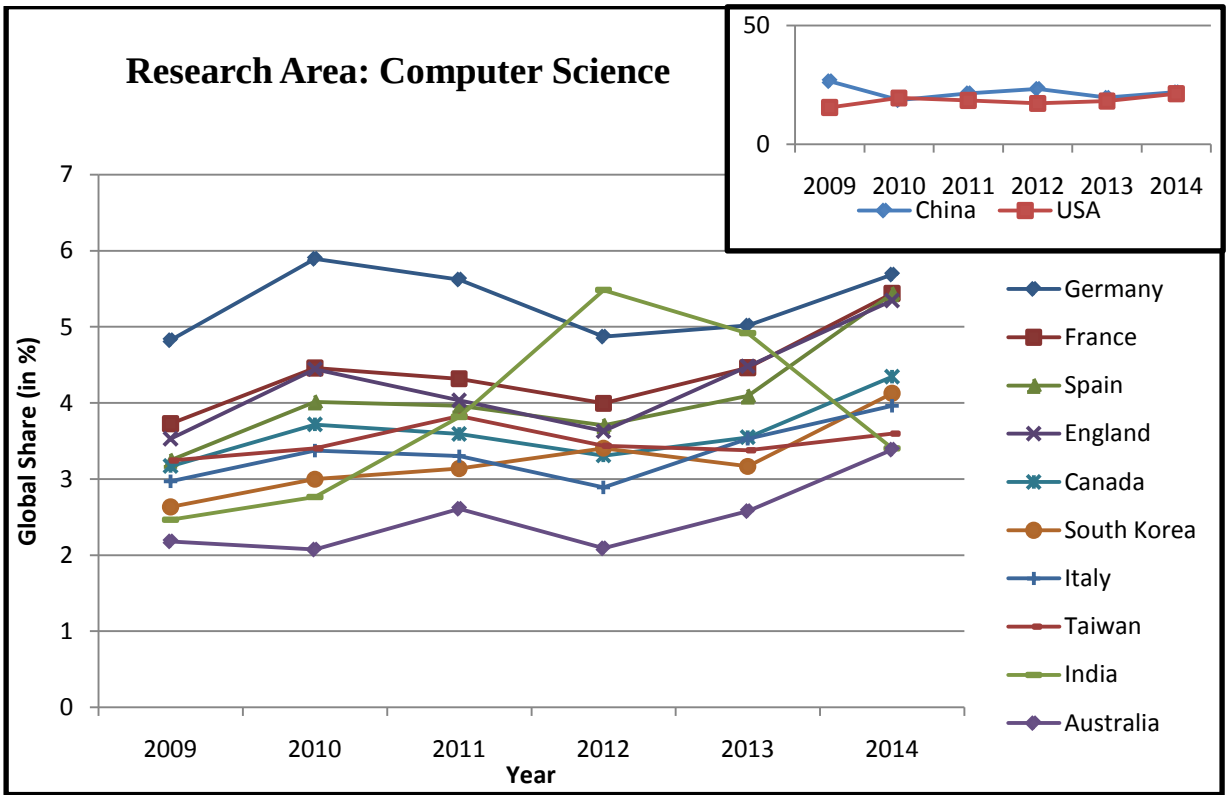

Figure 5. Global share of twelve most productive countries in Computer Science research area

Research Area: Computer Science

Research in the field of Computer Science is considered one of the thrust areas and a considerable number (624,995) of research articles has been published in this field during 2009-2014. China is number one in this field as per the global share is concerned (22.366%) during 2009-2014. USA holds the 2nd position with 17.725% global share. In Figure 5 research output of twelve most productive countries in Computer Science are compared in terms of global share during 2009-2014. Year wise research output in Computer Science shows that global share of China and USA are comparable. India has done remarkable improvement in Computer Science research during 2009 to 2013 and improved its ranking from 12th (2009) to 3rd (2012). Germany, France, England, Spain, South Korea, Italy, Canada are among twelve most productive countries in this field. Taiwan has improved its position in this field and its global share is more than that of Australia.

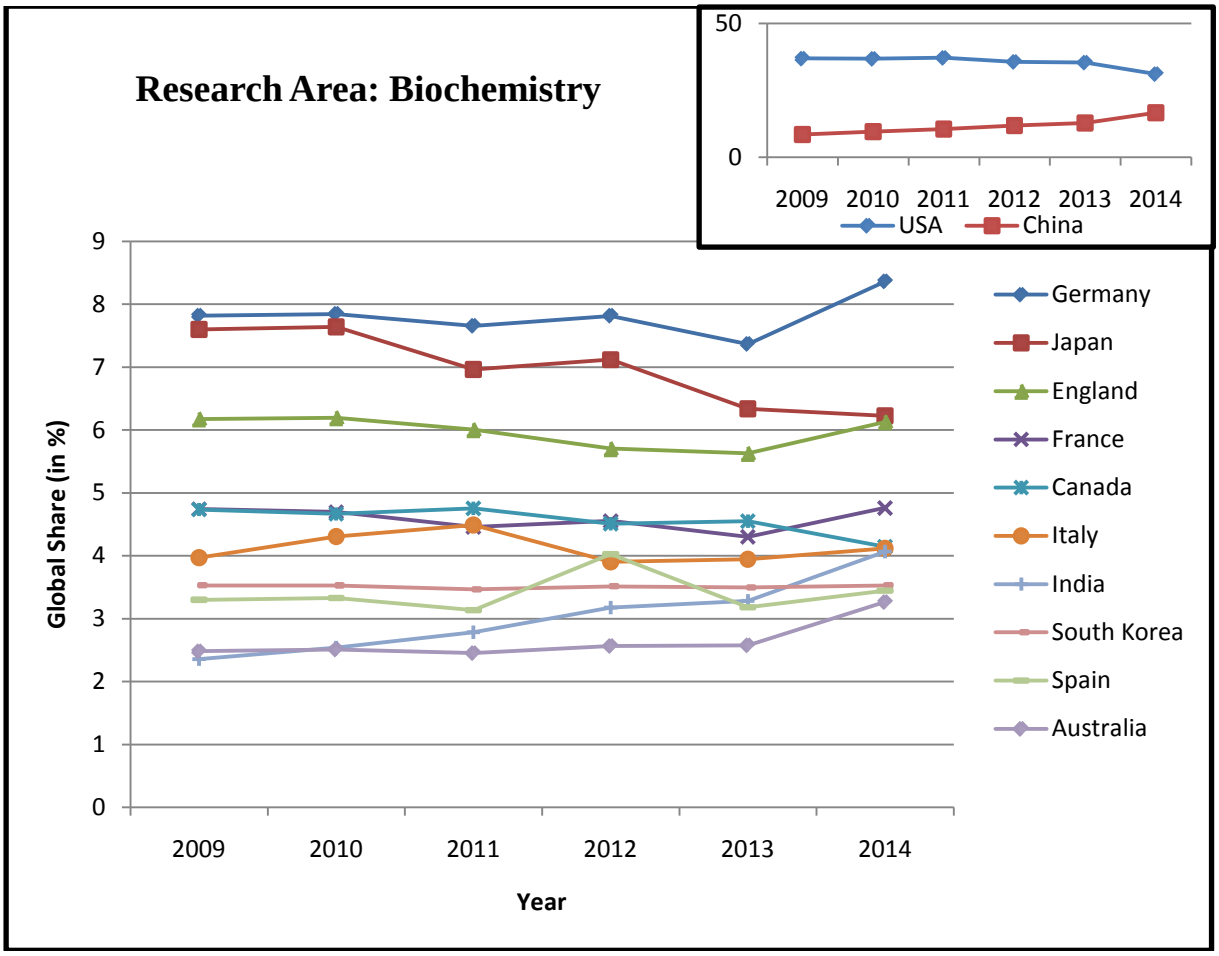

Figure 6. Global share of twelve most productive countries in Biochemistry Molecular Biology research area

Research Area: Biochemistry Molecular Biology

USA and China hold the 1st and 2nd rank in this area of research like almost all other subject areas as shown in Figure 6. But the remarkable thing is that China has gradually increased its output in this research area and in 2009 its rank was 7th whereas from 2010 onwards it ranks 2nd as shown in the graph. India slowly increases its output in this area. Germany, Japan and England are good in this area of research and they manage to hold their positions in between 3rd to 5th during the last six years although Japan's global share has been decreased. France, Canada and Italy are comparable and better than South Korea, Span and Australia in this research area.

Research Area: Neurosciences Neurology

Table 1 shows the global share of productive countries in Neurosciences Neurology research area. We see that USA is the leader with 34.962% global share followed by Germany with 8.518% global share. China has steadily increased its output and improved its position from 8th in 2009 to 4th in 2014. Japan's global share has been decreased during 2009-2014. India is comparatively far behind in this research area during the last six years but South Korea is among twelve most productive countries.

Table 1: Neurosciences Neurology

	Percentage of Publication during 2009-2014					
Country	2009	2010	2011	2012	2013	2014
USA	33.000	33.198	34.682	35.258	37.112	36.506
Germany	8.975	8.367	8.228	8.365	8.729	8.388
England	6.962	7.463	7.170	7.654	7.492	7.683
China	3.344	4.101	4.666	4.906	6.091	6.955
Canada	5.196	5.765	5.570	5.735	6.322	6.306
Italy	5.277	5.224	5.522	5.799	5.606	5.825
Japan	7.611	7.752	7.120	5.639	5.552	5.690
France	4.353	4.161	4.177	4.195	4.349	4.067
Australia	2.861	3.058	3.196	3.138	3.502	3.864
Netherlands	2.894	3.231	3.231	3.296	3.374	3.589
Spain	3.037	3.264	3.225	3.294	3.380	3.241
South Korea	2.599	2.506	2.263	2.598	2.554	2.680
India	1.232	1.371	1.337	1.504	1.560	1.577

India in global scenario

Ranking

Among the seven research areas considered in this study, India is within twelve most productive countries except for Neurosciences Neurology for the entire period from 2009-2014. Table 2 shows India's ranking in different research areas during 2009-2014. India's position was 5th during 2009-2013 for Chemistry but in 2014 India is on 3rd position surpassing Germany and Japan. India has improved its position gradually from 10th (2009) to 6th (2014) followed by China, USA, Germany, Japan and France in Physics research. India's ranking in Materials Science was 5th in 2013 after China, USA, South Korea and Japan. For the rest of the period the position is 6th behind Germany. In 2013 India's research output in Engineering was best (4th) followed by China, USA and Japan. India has improved its position considerably in engineering research during 2009 to 2014 and acquired 4th position in 2013. India has done remarkable improvement in Computer Science research also and improved its ranking from 12th (2009) to 3rd (2012) followed by China and USA. In Biochemistry India has slightly improved its position during this period in terms of global share.

Table 2. India's Position in different research areas in terms of global share

Research Areas	2009	2010	2011	2012	2013	2014
Physics	10	9	8	8	7	**6**
Chemistry	5	5	5	5	5	**3**
Materials Science	7	6	6	6	**5**	6
Engineering	11	12	11	6	**4**	6
Computer Science	12	12	9	**3**	4	11
Biochemistry Molecular Biology	12	11	11	11	10	**9**
Neurosciences Neurology	18	17	17	16	**16**	17

Table 3. India's output in different research areas for the period 2009-2014. India's growth rate (in %) is compared with global growth rate for each research area.

Research Areas	2009	2010 Growth in % for (India) (Global)	2011 Growth in % for (India) (Global)	2012 Growth in % for (India) (Global)	2013 Growth in % for (India) (Global)	2014 Growth in % for (India) (Global)
Physics	5925	6964 (17.53%) (-0.20%)	7598 (9.10%) (3.49%)	7910 (4.10%) (4.47%)	8819 (11.49%) (-1.54%)	7774 (-11.84%) (-19.38%)
Chemistry	8092	8555 (5.72%) (-0.37%)	9628 (12.54%) (9.12%)	10027 (4.14%) (5.49%)	10934 (9.04%) (3.42%)	10951 (0.15%) (-16.77%)
Materials Science	4607	4889 (6.12%) (8.00%)	5193 (6.21%) (24.91%)	5902 (13.65%) (10.50%)	7455 (26.31%) (1.01%)	5891 (-20.97%) (-21.73%)
Engineering	8426	6245 (-25.88%) (-15.55%)	6895 (10.40%) (2.22%)	10527 (52.67%) (24.35%)	11267 (7.02%) (-11.48%)	6226 (-44.74%) (-39.98%)
Computer Science	3969	2730 (-31.21%) (-38.60%)	3775 (38.27%) (0.06%)	5919 (56.79%) (9.15%)	4850 (-18.06%) (-8.62%)	1764 (-63.62%) (-47.45%)
Biochemistry Molecular Biology 1950		2099 (7.64%) (-0.14%)	2342 (11.57%) (1.76%)	2737 (16.86%) (2.37%)	2791 (1.97%) (-1.27%)	2719 (-2.57%) (-21.40%)
Neurosciences Neurology 1042		1121 (7.58%) (-3.29%)	1109 (-1.07%) ((1.40%)	1315 (18.57%) (5.35%)	1343 (2.12%) (-1.74%)	1121 (-16.53%) (-45.40%)

In terms of number of publications in a particular area by Indian scientists, India's performance is the best in Chemistry field. From Table 3, we see that growth rate in terms of number of publications is more than that of global growth rate during 2009-2014. India is also very good in Physics research area as it is evident from Table 3. Again growth rate of India is better than that of global growth rate in this field of research. The most promising feature is that during this period India has improved its ranking steadily in terms of global share. From Table 3 we see that Indian scientists have made considerable improvements in the fields of Materials Science, Engineering and Computer Science during this period. In Biochemistry Molecular Biology research area we see that India is not good as compared to Chemistry and Physics as shown from the data in Table 3. In this field India's contribution is (14,677) 3.002% in terms of global share during 2009-2014. In Neuroscience Neurology field India's contribution (1.430% of global share) is the least compared to other research areas considered in this paper.

Table 4. Countries with which Indian scientists collaborated during 2009-2014

Country	USA	Germany	England	South Korea	France	Japan	China	Canada	Australia	Italy	Spain
Percentage of Collaboration	6.28	2.27	2.01	1.74	1.61	1.39	1.24	1.18	1.13	1.12	0.91

Collaboration

India has a long tradition on collaboration with other countries in the field of S&T research. Total number of papers published by India in collaboration with other countries is 67,026 that are almost 20% of total papers published by Indian scientists during 2009-2014. Indian scientists have collaborated with 172 countries during this period. Table 4 shows the list of 10 most preferred countries with whom India has collaborated during 2009-2014. From Table 4 we see that USA is still the most preferred country for Indian scientists for collaboration. Out of total collaborating papers, 16.905% are in Physics followed by Chemistry (16.074), Materials Science (10.026%), Engineering (9.504%), Biochemistry Molecular Biology (4.631%), Computer Science (2.956%) and Neurosciences Neurology (1.711%) respectively.

Table 5 shows the preferred research areas in which Indian scientists publish more. Apart from the research areas considered in this paper, we see Pharmacology, Agriculture, Environment science and Mathematics as preferred research areas but not Neuroscience.

Table 5. Preferred research areas for Indian scientists

Research Areas	Chemistry	Engineering	Physics	Materials Sci.	Computer Sci	Pharmacology	Biochemistry	Agriculture	Environment Sci.	Microbiology	Mathematics
Percentage of Publication	16.79	14.25	12.97	9.76	6.64	5.11	4.18	3.64	3.08	2.79	2.63

Impact of Indian publications

In Table 6 we have shown the h-index and average citation per article of Indian publications in different research areas during 2009-2012. We see that h-index and average citation per article are maximum for papers published in Chemistry research area. The parameters are comparable for Physics, Materials science and Biochemistry and better than Engineering and Neuroscience.

Table 6. Citation and impact of Indian publications in different research areas during 2009-2012

Research Areas	2009		2010		2011		2012	
	h-index	Avg Citation per article	h-index	Avg Citation per article	h-index	Avg Citation per article	h-index	Avg Citation per article
Engineering	62	5.54	49	5.40	42	4.26	38	3.84
Chemistry	83	11.54	75	9.79	63	7.91	52	5.93
Physics	62	9.07	65	7.67	52	5.58	47	4.21
Materials Science	68	11.10	61	8.92	51	7.15	39	4.54
Computer Science	32	2.30	26	2.35	29	2.06	18	0.82
Neuroscience Neurology	33	7.13	28	5.26	24	3.81	19	2.65
Biochemistry Molecular Biology	45	10.73	43	9.60	37	7.64	30	4.94

Conclusions

This study clearly indicates the trends in major research areas during 2009-2014 for different countries. It is evident from the results that performance of different countries is not same for all research areas. China has made remarkable improvement in Materials Science and Engineering. In Physics, Chemistry and Computer Science USA and China are competing. But in Neuroscience Neurology, USA is far ahead of China and others. Amongst the seven research areas considered here, India's performance is the best for Chemistry. India is doing well in traditional subjects like Physics and Chemistry. Also India is progressing considerably in Engineering, Materials Science and Computer Science. But India is still lagging behind in Medical and Biosciences research areas as evident from the results. Other Asian countries namely China, South Korea and Taiwan are also weak in these research domains compared to USA and established European countries. South Korea's contribution has been increased in all the research areas considered in this study except in Neuroscience Neurology. Iran has progressed in the fields of Chemistry and Engineering. Taiwan has improved in the fields of Materials Science and Computer Science. Surprisingly Japan's contribution in terms of global share has been decreased in almost all research areas considered here during 2009-2014. Germany, France, England, Italy, Spain are amongst twelve most productive countries in all research fields considered in this study during 2009-2014 although their contributions have been decreased slightly. Canada and Australia is amongst twelve most productive countries in these research areas. We see Russia amongst twelve most productive countries in Physics and Chemistry but Brazil is not there amongst BRIC countries for these research areas during 2009-2014.

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