Scientometric Study of Mathematics Research among BRICS Countries as reflected in Web of Science database during 2011-2015

Kiran P. Savanur
Department of Library and Information Science,
Rani Channamma University, Vidyasangama,
Belagavi – 591 156, Karnataka, India.
Email: kiranpsavanur@gmail.com
S. M. Bakanetti
Department of Library and Information Science,
Rani Channamma University, Vidyasangama,
Belagavi – 591 156, Karnataka, India.

Abstract

BRICS has emerged as a major growing economic consortium. The five country group which is overtaking the elite developed nations and growing at a faster rate has various motives and visions in research sector as well. Hence this study, Scientometric analysis can be used to analyze the trends of mathematical research among the BRICS countries, it was found that, the combined publication output of BRICS steadily increased from 23.87% to 30.13%. The Mean Relative Growth Rates and Doubling time of the BRICS lie within close range to each other, though highest among them is 0.46 that of China and Doubling time equal to 1.74. The research trend in Mathematics was collaborative, as the 88% of articles are collaborative. The Activity Index was 1.18 and 1.17 for Russia and Brazil respectively in the year 2015. In the same year, the attractive indices were 0.11 for Russia and 0.10 for China and Brazil each. The Publication Efficiency Index was 0.16 for China and 0.15 for India in the year 2015.

Keyboard: Mathematics, BRICS, Literature growth, Collaboration, Authorship, Scientometric Indices.

1. Introduction

Mathematics is known as the language of the Universe, began from the day when man started to count. In the Current era, Mathematics has its ramifications in each and every field. Mathematics is the subject worthy of collaboration as all the sectors of the economy, Science, Engineering employs advanced Mathematical ideas. So there is a huge research going on, many interdisciplinary structures forming and due to the advancements in computing the research output is growing at the unusually high rate. This involves collaborations among countries, institutions and scientists which have to be studied. Hence, in the present study, we have considered the research output of Mathematics among

BRICS countries from the year 2011-2015.

1.1 *BRICS*

BRICS is an international association of five emerging countries. They are major emerging economies in the world. Brazil, Russia, India, China and South Africa are in this group. The collaboration between them significantly impacts their development and the global economy. The BRICS share of the global Economy in terms of GDP grew from 11% in 1990 to 25% in 2011. Analysts predict that the BRICS will overtake US in terms of GDP this year and the G7 by 2030.[1] Hence this study can be used to analyze the trends of mathematics research among the BRICS countries and also provide with a latest numbers and figures which can be used as a base in formulating any collaborative research activity among the BRICS countries.

1.2 *Objectives*

The main objectives of this paper are as follows:

1. To find out year-wise growth of publications, compare the output to that of the world.
2. To find out relative growth rates and doubling time of publications.
3. To find out authorship pattern.
4. To find out different measures of Collaboration.
5. To measure different Scientometric Indicators such as Collaborative Index, Degree of Collaboration, Collaborative Coefficient, Modified Collaborative Coefficient, Activity Index, Attractive Index and Publications Efficiency Index.

2. Methodology

The publication data included in the present study was collected from the Web of Science (WoS) database, currently publishing from Thomson Reuters, the USA for the period 2011-15 i.e. 5 years. The keyword “Mathematics” was used to retrieve all the publications data and the all the fields were downloaded for each of the countries of the BRICS by using the country name. The total records obtained for Brazil was 5841, Russia – 10069, India – 7805, China – 57995, South Africa – 1986. Only the required fields were used for analysis like Author field, Publisher, Publishing year, Total Citations, Journal name, Keyword plus etc. Data were analyzed by using the Excel software.

3. Data Analysis

The analysis is done to map the literature, compare the research output among BRICS countries and compare BRICS output with the world output, Author Collaboration patterns and Keyword analysis and Clustering.

3.1 Year-wise distribution of articles and citations

Table-1
Year-wise publications of BRICS

No. of Authors	2011	2012	2013	2014	2015	Total	Percentage of total
1 authored	88	96	85	74	63	406	20.44
2 authored	123	166	163	172	164	788	39.68
3 authored	89	95	112	132	105	533	26.84
4 authored	23	22	40	46	49	180	9.06
5 authored	7	2	11	14	13	47	2.37
6 authored	3	3	3	6	1	16	0.81
7 authored	1	1	1	1	2	6	0.30
8 authored	0	0	0	2	0	2	0.10
9 authored	1	0	0	0	1	2	0.10
10 authored	0	0	0	0	0	0	0.00
above 10 authors	1	1	4	0	0	6	0.30
Total	336	386	419	447	398	1986	

The yearly publications of BRICS countries from 2011-2015 are shown in table-1 and figure-1. The total publications of all the BRICS countries are 83,696. A maximum number of contributions was made by China with a total of 57,995 articles which is 69.29 %. Brazil has the lowest number with 5,841 articles making 6.98 % of the total. The year of maximum output for India, Brazil and Russia is 2015; and 2014 for China and South Africa. A study by Karpagam, et al. (2012) reveals that China is the only country which belongs among the top 10 countries in stem cell research productivity, SNAP members and E7 countries.

The growth rate is measured using the formula of CAGR or Compound Annual Growth Rate (Wikipedia, 2013). It gives the averaged rate of increase per year. The value is appropriate for comparing the growth rates between different countries.

$$CAGR = \left\{ \left[\frac{Ending\ Value}{Beginning\ Value} \right]^{\frac{1}{n-1}} - 1 \right\}$$

Where *n* is the number of years. In our case *n*=5.

China has the maximum growth rate of 9.89 followed by Brazil with 6.02. South Africa has the lowest growth rate of 4.32.

Table 2 shows the total output of BRICS countries as a single unit in comparison with the world output.

Table 2

Comparison between BRICS output to that of the world.

Year	BRICS output	World output	% share of BRICS
2011	13863	58069	23.87
2012	15168	58898	25.75
2013	17151	61450	27.91
2014	18587	62515	29.73
2015	18927	62827	30.13
Total	*83696*	*303759*	*27.48*
Year	**Citation received by BRICS**	**Citations of the world**	**% share of BRICS**
2011	65818	280557	23.46
2012	55887	214434	26.06
2013	40397	146963	27.49
2014	23022	81368	28.29
2015	7091	25438	27.88
Total	*192215*	*748760*	*26.64*

The total BRICS share has been consecutively increasing in the total output as the numbers indicate in the above table. The increment has occurred from 23.87% in 2011 to 30.13% in the year 2015. Even the Citation ratio has increased from 23.46% in 2011 per cent to 28.29% in 2014 and a slight decrease to 27.88% in the year 2015. Therefore BRICS as a developing economy even shares a considerable amount of research output being more than a quarter in the Mathematical field.

Figure 1

Year-wise growth-rate of articles of BRICS.

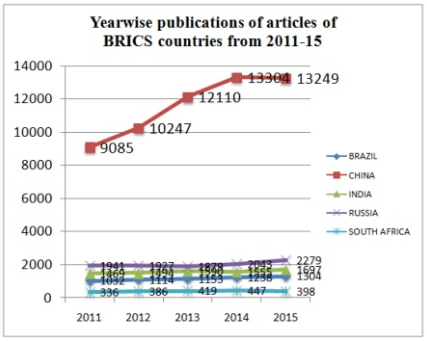


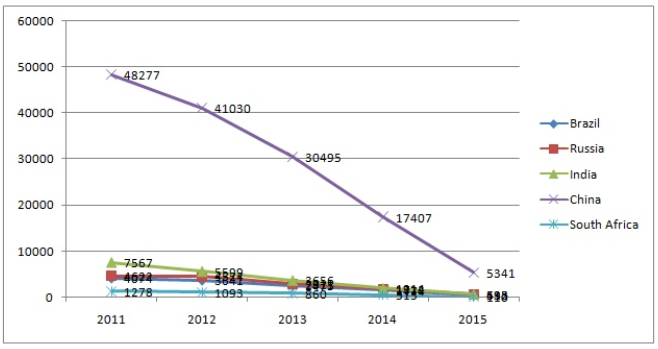
Table-3
The Year-wise growth of citations.

Sl. No	Country	2011	2012	2013	2014	2015	Total Citations	% of Citations	Cumulative Values	% of Cumulative Values
1	India	7567	5599	3656	1914	613	19349	10.07	19349	10.07
2	China	48277	41030	30495	17407	5341	142550	74.16	161899	84.23
3	Brazil	4074	3641	2475	1474	432	12096	6.29	173995	90.52
4	Russia	4622	4524	2911	1712	595	14364	7.47	188359	97.99
5	South Africa	1278	1093	860	515	110	3856	2.01	192215	100

The year-wise distribution of Citations of BRICS countries is shown in table 2 and the growth rate is plotted in figure 2. Of the total citations (1,92,215), China has the maximum number i.e. 1,42,550 (74.16 %) and the minimum is that of South Africa with 3,856 Citations (2.01 %). India has the maximum ratio of 'average citations per paper' per year (2.47) followed by China (2.45) and least being that of South Africa (1.94).

Figure 2

Relative growth rate and Doubling time of Mathematics literature from 2011-2015.



The *Relative Growth Rate (RGR)* is a quantity indicator used in measuring and testing exponential growth rates or continuous growth rates per unit time. It gives a relative rate which is dependent on the size of the size of the population unlike that of absolute linear growth rates. The RGR is used most often by Botanists for measuring the growth of plant biomass per unit of time (Sangam, S. L. et al. 2014).

$$RGR = \frac{\ln W_2 - \ln W_1}{T_2 - T_1}$$

Where W_2 is the Final number;

W_1 is the Initial number;

T_2-T_1 is the difference between Final and Initial times.

Doubling Time is the Time it takes for the number of publications to double while growing at the same rate. It is synchronous to the Relative Growth Rate as both are exponential measures. The doubling time and Relative growth rates are inversely proportional to each other.

$$\text{Doubling Time, DT} = \frac{\ln 2}{RGR} = \frac{0.693}{RGR}$$

Table 4

RGR and Doubling time of BRICS from 2011-15.

BRAZIL						
Year	Total Publications	Cumulative values	RGR	Mean RGR	DT	Mean DT
2011	1032	1032	-		-	
2012	1114	2146	0.73		0.95	
2013	1153	3299	0.43		1.61	
2014	1238	4537	0.32		2.17	
2015	1304	5841	0.25	0.43	2.74	1.87
CHINA						
Year	Total Publications	Cumulative values	RGR	Mean RGR	DT	Mean DT
2011	9085	9085	-		-	
2012	10247	19332	0.76		0.92	
2013	12110	31442	0.49		1.42	
2014	13304	44746	0.35		1.96	
2015	13249	57995	0.26	0.46	2.67	1.74
INDIA						
Year	Total Publications	Cumulative values	RGR	Mean RGR	DT	Mean DT
2011	1469	1469	-		-	
2012	1494	2963	0.70		0.99	
2013	1590	4553	0.43		1.61	
2014	1555	6108	0.29		2.36	
2015	1697	7805	0.25	0.42	2.83	1.95
RUSSIA						
Year	Total Publications	Cumulative values	RGR	Mean RGR	DT	Mean DT
2011	1941	1941	-		-	
2012	1927	3868	0.69		1.01	
2013	1879	5747	0.40		1.75	
2014	2043	7790	0.30		2.28	
2015	2279	10069	0.26	0.41	2.70	1.93
SOUTH AFRICA						
Year	Total Publications	Cumulative values	RGR	Mean RGR	DT	Mean DT
2011	336	336	-		-	
2012	386	722	0.76		0.91	
2013	419	1141	0.46		1.51	
2014	447	1588	0.33		2.10	
2015	398	1986	0.22	0.44	3.10	1.90

rom the table 4 it can be inferred that none of the countries follows an exponential or continuous growth rate as the values of RGR is decreasing. The mean values of RGR are almost the same i.e. the values lie between the close range of 0.41 to 0.46. The mean *Doubling Time* is lesser in case of China which is 1.74 and highest for India with 1.95. But the value of *doubling time* in 2015 is 3.10; more in the case of South Africa and 2.67; less in China whereas in India it is 2.83.

3.3 Authorship pattern study among BRICS in producing Mathematics Literature.

In this section, an attempt has been made to study the authorship pattern by counting single and multi-authored papers. This study helps to find out collaboration patterns and related scientometric indicators.

Table 5.1

Authorship pattern of BRAZIL.

No. of Authors	2011	2012	2013	2014	2015	Total	Total Percentage
1 authored	130	138	158	157	153	736	12.60
2 authored	412	375	419	445	472	2123	36.35
3 authored	325	364	368	413	446	1916	32.80
4 authored	116	157	149	162	165	749	12.82
5 authored	37	42	35	41	39	194	3.32
6 authored	7	19	12	15	11	64	1.10
7 authored	3	10	8	2	11	34	0.58
8 authored	2	7	1	2	4	16	0.27
9 authored	0	0	0	0	0	0	0.00
10 authored	0	1	0	0	2	3	0.05
above 10 authors	0	1	3	1	1	6	0.10
Total	1032	1114	1153	1238	1304	5841	

As seen from the above table 5.1, double authored contributions are more in number, equal to 2,123 (36.35 %). Single-authored papers contribute only to 12.60 %. It can also be observed that in 2015, 472 papers were two authored papers which is the highest number of multi-authored paper. Therefore 2 and 3 authored papers are more frequent when it comes to author collaboration.

Table 5.2

Authorship pattern of CHINA.

No. of Authors	2011	2012	2013	2014	2015	Total	% of Total
1 authored	1377	1578	1690	1726	1651	8022	13.83
2 authored	3600	3852	4266	4659	4498	20875	35.99
3 authored	2794	3102	3769	3987	4118	17770	30.64
4 authored	904	1205	1561	1910	1933	7513	12.95
5 authored	270	348	539	682	686	2525	4.35
6 authored	78	107	175	203	222	785	1.35
7 authored	33	19	68	79	79	278	0.48
8 authored	18	18	18	35	35	124	0.21
9 authored	3	10	13	10	8	44	0.08
10 authored	2	2	4	6	11	25	0.04
Above 10 authors	6	6	7	7	8	34	0.06
Total	9085	10247	12110	13304	13249	57995	

According to the data in table 5.2, two and three authored papers are prominent. Out of 57,995 total publications, 20,875 papers (35.99 %) and 17,770 papers (30.64 %) are the number of two authored and three authored papers respectively. Single-authored papers account only to 8,022(13.83 %). For all the five years 2011-15, two authored papers are consistent in being the highest multi-authored contributions of Chineseauthors.

Table 5.3
Authorship pattern of INDIA.

No. of Authors	2011	2012	2013	2014	2015	Total	% of total
1 authored	225	195	237	186	216	1059	13.57
2 authored	674	661	714	681	764	3494	44.77
3 authored	406	428	441	479	508	2262	28.98
4 authored	119	155	142	161	155	732	9.38
5 authored	28	39	42	32	34	175	2.24
6 authored	12	14	8	12	13	59	0.76
7 authored	5	1	4	1	4	15	0.19
8 authored	0	1	0	1	0	2	0.03
9 authored	0	0	0	0	1	1	0.01
10 authored	0	0	0	1	0	1	0.01
above 10 authors	0	0	2	1	2	5	0.06
Total	1469	1494	1590	1555	1697	7805	

Two and three authored papers are the most prominent ones as seen from the table 5.3, two authored papers account for 44.77 % i.e. 3,494 and three authored papers account for 28.98 %, the lowest being that of 9 and 10 authored papers.

Table 5.4
Authorship pattern of RUSSIA.

No. of Authors	2011	2012	2013	2014	2015	Total	Percentage of total
1 authored	908	880	845	912	937	4482	44.51
2 authored	647	652	662	669	773	3403	33.80
3 authored	283	275	273	314	371	1516	15.06
4 authored	58	82	69	96	128	433	4.30
5 authored	26	20	17	32	40	135	1.34
6 authored	8	9	7	7	15	46	0.46
7 authored	5	4	0	4	6	19	0.19
8 authored	3	2	3	4	2	14	0.14
9 authored	1	1	0	3	2	7	0.07
10 authored	0	0	0	1	1	2	0.02
above 10 authors	2	2	3	1	4	12	0.12
Total	1941	1927	1879	2043	2279	10069	

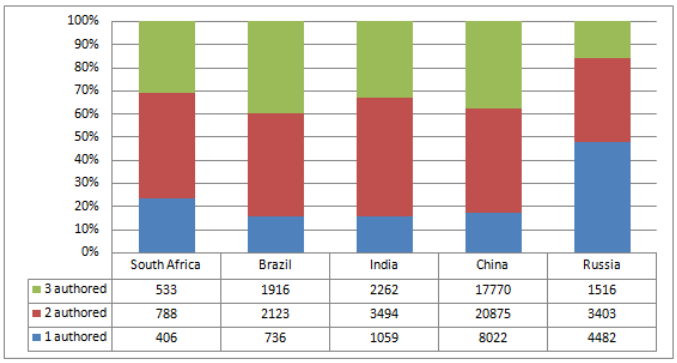
From the table 5.4, it is observed that single-authored papers are prominent in Russia accounting for 44.51 % which is 4482 papers. The total number of two authored papers is 3403(33.80 %).

Table 5.5
Authorship pattern of SOUTH AFRICA.

No. of Authors	2011	2012	2013	2014	2015	Total	Percentage of total
1 authored	88	96	85	74	63	406	20.44
2 authored	123	166	163	172	164	788	39.68
3 authored	89	95	112	132	105	533	26.84
4 authored	23	22	40	46	49	180	9.06
5 authored	7	2	11	14	13	47	2.37
6 authored	3	3	3	6	1	16	0.81
7 authored	1	1	1	1	2	6	0.30
8 authored	0	0	0	2	0	2	0.10
9 authored	1	0	0	0	1	2	0.10
10 authored	0	0	0	0	0	0	0.00
above 10 authors	1	1	4	0	0	6	0.30
Total	336	386	419	447	398	1986	

From the table 5.5, it is observed that 788 two authored papers (39.68 %) are highest followed by 533 three authored papers (26.84 %). It can also be seen that except for four authored papers number of papers after 2014 have decreased which is in contrast to the increasing trend from 2011 to 2014. In figure 3, the differences between single, double and triple authored papers can be discerned easily.

Figure 3
Comparison between single, double and triple authored papers between BRICS.



3.4 Measures of Collaboration among authors of BRICS in producing Mathematics Literature from 2011-15.

The collaboration between authors and that too authors between different countries brings in more consolidated and stronger results because such results suit to different scenarios and conditions as tested and evaluated by the respective scientists of the different countries. Scientometric indicators strive to measure the factors and coefficients which govern and quantify the collaborations between the authors. But not all indicators provide an insight about the collaborative patterns.

Collaborative Coefficient (CC): Proposed by (Ajiferuke et al., 1988). It gives a proper number which expresses the level of collaboration. The shortcomings of *Collaborative Index* and *Degree of Collaboration* are solved by CC. The Collaborative Coefficient lies between 0 and 1. The result yields 0 for only single-authored papers and a digit nearer to 1 for all maximal multi-authored papers (Savanur & Srikanth, 2009).

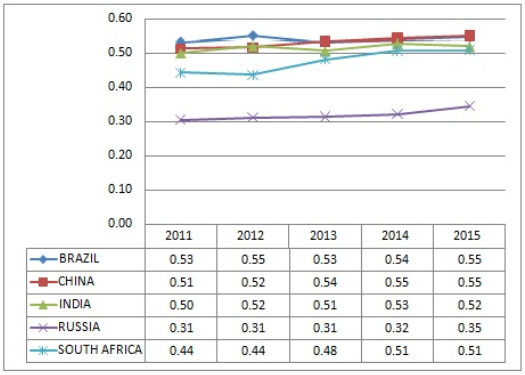
$$\text{Collaborative Coefficient} = 1 - \frac{\sum_{j=1}^{A} \frac{f_j}{j}}{N}$$

where f_j is the number of papers having j authors in collection *K*;

N is the total number of papers in *K*.

A is the total number of authors in collection *K*.

Figure 4
Collaborative Coefficient of BRICS from 2011-15



	2011	2012	2013	2014	2015
BRAZIL	0.53	0.55	0.53	0.54	0.55
CHINA	0.51	0.52	0.54	0.55	0.55
INDIA	0.50	0.52	0.51	0.53	0.52
RUSSIA	0.31	0.31	0.31	0.32	0.35
SOUTH AFRICA	0.44	0.44	0.48	0.51	0.51

The Collaborative Coefficient is highest in 2015 for Brazil and China. Russia has the lowest Collaborative coefficient but with an increasing trend. Similarly, other BRICS countries follow an increasing trend. India, Brazil and China have the highest coefficients.

3.5: Measure of Scientometric Indicators: Activity Index(AI), Attractive Index(AAI) and Publication Efficiency Index(PEI).

Activity Index: The Activity Index is used to compare the scientific output of a country with that of the world (Chen & Guan, 2011), (Hu & Rousseau, 2009).

$$\text{Activity Index, } AI_i^t = \frac{P_i^t}{\sum P} \Big/ \frac{TP^t}{\sum TP}$$

Where P_i^t is the Publication of i^{th} Country in the t^{th} year, $\sum P$ is the total publications of the i^{th} country during the entire period. TP^t is the total publication output of the world in the t^{th} year, and $\sum$ TP is the total Publications of the world during the entire period.

The Activity Indices of all BRICS countries is given in the following table and it shows an increase in a number of publications compared to the world output. China has the highest AI of 1.20. South Africa shows a decrease in AI from 1.18 in 2014 to 1.05 in 2015.

Table: 6

Activity Indices of BRICS from 2011-15

Activity Index						
Year	**2011**	**2012**	**2013**	**2014**	**2015**	
India	0.98	1.00	1.07	1.04	1.14	
China	0.82	0.92	1.09	1.20	1.20	
Brazil	0.92	1.00	1.03	1.11	1.17	
Russia	1.01	1.00	0.98	1.06	1.18	
South Africa	0.89	1.02	1.10	1.18	1.05	
Publications						
Country	**2011**	**2012**	**2013**	**2014**	**2015**	**Total Publications**
India	1469	1494	1590	1555	1697	7805
China	9085	10247	12110	13304	13249	57995
Brazil	1032	1114	1153	1238	1304	5841
Russia	1941	1927	1879	2043	2279	10069
South Africa	336	386	419	447	398	1986
World	58069	58898	61450	62515	62827	303759

Attractive Index: Attractive Index is used to measure the Impact of a country with that of the world through the number of Citations it has received during the year (Chen & Guan, 2011), (Hu & Rousseau, 2009).

$$\text{Attractive Index, } AAI_i^t = \frac{C_i^t}{\sum C} \Big/ \frac{TC^t}{\sum TC}$$

Where C_i^t is the Citations received by the i^{th} Country in the t^{th} year, $\sum C$ is the total Citations of the i^{th} country during the entire period. TC^t is the total Citations of the world in the t^{th} year, and $\sum TC$ is the total Citations of the world during the entire period.

The Attractive Indices of all BRICS countries is shown in the table below. India had a highest AAI, 1.04 in the year 2011 and decreased to lowest .08 in 2015 with a decrease in the number of Citations in par with other BRICS countries. As for the year 2015, Russia has the highest AAI of 0.11.

Table: 7

Attractive Indices of BRICS from 2011-15

Attractive Index						
Year	**2011**	**2012**	**2013**	**2014**	**2015**	
India	1.04	0.77	0.50	0.26	0.08	
China	0.90	0.77	0.57	0.33	0.10	
Brazil	0.90	0.80	0.55	0.33	0.10	
Russia	0.86	0.84	0.54	0.32	0.11	
South Africa	0.88	0.76	0.60	0.36	0.08	
Citations						
Country	**2011**	**2012**	**2013**	**2014**	**2015**	**Total Citations**
India	7567	5599	3656	1914	613	19349
China	48277	41030	30495	17407	5341	142550
Brazil	4074	3641	2475	1474	432	12096
Russia	4622	4524	2911	1712	595	14364
South Africa	1278	1093	860	515	110	3856
World	280557	214434	146963	81368	25438	748760

Publications Efficiency Index: This indicator is used to measure the Impact of a country with that of the world based on the ratio of Citations and Publications (Guan & Gao, 2008).

$$PEI^t_i = \frac{C_i^t}{\sum C} \Big/ \frac{P_i^t}{\sum P}$$

Where C_i^t is the Citations of the i^{th} country, $\sum C$ is the total number of Citations received by the i^{th} country during the entire period, P_i^t is the publications of the i^{th} country, $\sum P$ is the total number of Publication of the i^{th} country during the entire period.

The following table shows the Publication Efficiency Index of BRICS Countries.

Table:8.

Publication Efficiency Indices of BRICS from 2011-15

Publication Efficiency Index						
Year	**2011**	**2012**	**2013**	**2014**	**2015**	
India	2.09	1.52	0.93	0.50	0.15	
China	2.16	1.62	1.02	0.53	0.16	
Brazil	1.60	1.33	0.87	0.48	0.13	
Russia	0.97	0.95	0.63	0.34	0.11	
South Africa	1.54	1.15	0.83	0.47	0.11	
Publications						
Country	**2011**	**2012**	**2013**	**2014**	**2015**	**Total Publications**
India	1469	1494	1590	1555	1697	7805
China	9085	10247	12110	13304	13249	57995
Brazil	1032	1114	1153	1238	1304	5841
Russia	1941	1927	1879	2043	2279	10069
South Africa	336	386	419	447	398	1986
World	58069	58898	61450	62515	62827	303759
Citations						
Country	**2011**	**2012**	**2013**	**2014**	**2015**	**Total Citations**
India	7567	5599	3656	1914	613	19349
China	48277	41030	30495	17407	5341	142550
Brazil	4074	3641	2475	1474	432	12096
Russia	4622	4524	2911	1712	595	14364
South Africa	1278	1093	860	515	110	3856
World	280557	214434	146963	81368	25438	748760

Some of the findings of the study are highlighted below:

- There were 5841, 10069, 7805, 57995, 1986 Publications of Brazil, Russia, India, China and India respectively yielding a total of 83,696 during the year 2011-2015. During the same period, the total World output was 3, 03,759.

- China contributed a maximum number of articles which is 69.29% along with highest CAGR value of 9.89.

- The combined publication output of BRICS steadily increased from the year 2011 to 2015 i.e. 23.87% to 30.13%.

- The mean Relative Growth Rates and Doubling time of the BRICS lie within close range to each other, though highest among them is .46 that of China and Doubling time equal to 1.74.

- Three authored publications were prominent in South Africa, two authored in India and China and single-authored in Russia.

- The Collaborative Indices was found for each of the countries, the highest collaborative Coefficient in 2015 was 2.76 for China followed by Brazil, 2.75. The highest Degree of Collaboration in 2015 is .88 for China and Brazil followed by .87 of India. The highest Collaborative coefficient is .55 for Brazil and China in the year 2015. The modified Collaborative Coefficient was also .55 for Brazil and China.

- The Activity Index was 1.18 and 1.17 for Russia and Brazil respectively in the year 2015. In the same year, the attractive indices were .11 for Russia and .10 for China and Brazil each. The Publication Efficiency Index was .16 for China and .15 for India in the year 2015.

4.Conclusion

The results derived from the above analysis show the impact of publications. The total output of BRICS in Mathematics subject is increasing yearly. The average share of BRICS countries for the year range of 2011-2015 is 27.48% and Citation share of 26.64% of the world output in Mathematics field. The growth studies show the increasing trend, particularly in China. However more collaborative efforts have to be carried out between the authors of the countries if research has to have a conspicuous impact on the economic factors and scientific development of BRICS as a whole.

References

http://www.gdforum.org

R. Karpagam S. Gopalakrishna, B. Ramesh Babu, M. Natarajan. Scientometric analysis of stem cell research: A comparative study of India and other countries; *COLLNET Journal of Scientometrics and Information Management* (2012).

S.L.Sangam Shivaranjini S.Mogali.Mapping of Indian Social Science Literature*; Collnet journal of Scientometrics and Information Management*,8(1), 2014.

https://en.wikipedia.org/wiki/Relative_growth_rate

Ajiferuke I., Burrel, Q., & Tague, J. (1988). Collaborative coefficient: A single measure of the degree of collaboration in research. Scientometrics, 14, 421–433.

Kiran Savanur, R. Srikanth. Modified collaborative coefficient: a new way to measure for quantifying the degree of research collaboration; *Scientometrics*(2009); 84:365-371.

Chen K. & Guan, J. (2011). A bibliometric investigation of research performance in emerging nanobiopharmaceuticals. *Journal of Informetrics*, 5(2), 233-247.

Hu X., & Rousseau, R. (2009). A comparative study of the difference in research performance in biomedical fields among selected Western and Asian countries; *Scientometrics*, 81(2), 475-491.

Guan J and Gao X. Comparison and evaluation of Chinese research performance in the field of bioinformatics, *Scientometrics*, Vol. 75(2), 2008, pp. 357–379.