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Digital library research in BRICS countries during 2000-2019: a scientometric analysis

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The study examines 1220 digital library research papers published by BRICS countries during the period 2000 to 2019. Bibliographic data on the research papers were collected from Web of Science database. It is found that maximum number of publications (225) were two-authored. The Degree of collaboration is 0.84, collaborative index is 4.14, the collaboration co-efficient is 0.59 and the modified collaboration co-efficient is 0.61. Among all the BRICS countries, China has contributed the most number of papers [690 (56.58%)] followed by India with 205 (16.80%) contributions. Lotka's law was not found to fit with the observed author's productivity of the study. The study concludes that there is increased research on digital library in BRICS countries.

Keywords: Scientometrics; Bibliometrics; Authorship pattern; Digital libraries; Electronic libraries; Virtual libraries; Authorship index; Modified collaborative co-efficient; BRICS countries; Lotka's law

Introduction

Scientific output in the form of scholarly contributions communicated through documentary form is significant to the scientific research community. It can be measured through scholarly publications and data about citations[1]. Scientometrics analysis deals with the quantitative features and characteristics of science and scientific research output analysis to assess the products of science communication. Scientometric indicators play a significant role in research and development through assessing the scholarly communication across the subject.

In USA, in 1994-1998, six big digital library projects were initiated namely, University of Michigan Digital Libraries Research Project, Building the interspace: Digital library infrastructure for a university engineering community, the Environment Electronic library, Infor media, Stanford Integrated Digital Library Project, and the Alexandria Project. In U.K, the electronic library project at De Montfort University, Leicester namely, ELINOR Electronic Library Project which concluded in 1996 was the first digital library project followed by the UK Electronics Library Programme and British Library's Digital Library Programme.[2]

In India too, many digital library projects have been initiated. Some of the prominent digital library projects include Digital Library of India (2003), Kalasampada (IGNCA), National Mission for Manuscripts, Shodhganga, E-Shodhsindhu and National Digital Library (NDL, IIT-Kharagpur).

Research output on digital libraries are published in journals such as *Global Journal on Digital Libraries*, *D-Lib Magazine*, *World Digital Libraries*, etc., and are presented in conferences such as the International Conference on Digital Libraries (ICDL), European Conference on Digital Libraries (ECDL), International Conference on Asian Digital Libraries (ICADL), the Joint ACM/IEEE meetings on digital libraries etc. UNESCO and 32 other collaborative institutions launched a dedicated site – "World Digital Library" on April 21, 2009, which stores the cultural materials of different libraries around the world.

Scientometric studies on digital library research reflect the growth of literature in this field.[3-5] There is scope for more scientometric studies in digital libraries, especially to compare the research output of a group of similar countries like BRICS. Brazil, Russia, India, China and South Africa are five emerging economies, and it is useful to study the research productivity of these nations in different subject areas. This scientometric study is undertaken to understand and describe the current state of digital

library research based on literature published by BRICS countries.

Review of literature

Digital library is one of important areas of research in library and information science subject and some scientometrics study have been conducted in recent past.

Shukla and Verma[3] conducted a scientometrics assessment on digital library research in India during 1989-2018 based on Scopus and found that out of a total of 1068 publications, the highest 108 (10.11%) of research papers were published in the year 2016 and out of 1068 publications, the maximum 398 research papers were published by two authors. The maximum (300) annual growth rate was recorded in the year 1997 and the overall degree of collaboration was 0.81. The most prolific author was Shalini Urs with 13 publications.

Ahmed et.al[4] conducted a bibliometric study on digital library output of world during 2002-2016. They found that 4,206 digital library-related literatures were published during the study period. The publication was in uptrend from later to early period of the study. USA was found to have contributed highest 38.94% literature total publications. Among the most prolific authors, three authors were each from the USA and UK, two authors from Brazil and one author each from South Africa, China and Germany.

Gupta[5] et. al. conducted scientometrics assessment of global output on digital library research during 2007-16 and found that 12104 publications were published on digital library and maximum contribution was from the U.S.A with 26.89% share while highest number (30.86%) of articles belonged to the computer science discipline.

Mustafa[6] in his study analysed 88 articles of *World Digital Libraries: An International Journal*, published during the year 2008–14 and examined the year-wise distribution, institution-wise distribution, country-wise distribution, and contributions and length of articles in each volume. The study found that the highest number of articles during the period was contributed by India, and most are single-authored papers.

Singh et al[7] in their study examined the research productivity of digital libraries during the period 1998-2004 by using the LISA database. They have analysed the growth of 1,062 articles during the period 1998-2004. It was found that most articles (61%) are single-authored author papers and are not in concurrence with Lotka's Law. Maximum number of articles were in the journal *D-lib Magazine*.

Sood et al[8] did an assessment of digital library publication during 2006 to 2015 and found that out of 17268 digital library papers, highest paper was published in the year 2013 followed by the year 2007. Fox E A and Urs S R have produced the maximum number of papers during the period.

Antony et al[9] analysed the digital library publications during 2009 to 2018 and found that higher number of publications was reported in the year 2014 with (0.45%) publications with highest EGR. During the study period, the mean relative growth rate was 0.24 and the mean doubling time of digital library publications is 4.37 years. The English was the most prominent language of communication in digital library research with 89.92% publications. Herrera-Viedma E has contributed highest number of publications 10 (1.53%).

From the above review of literature, it has been found that authors conducted the different scientometric study to examine the authorship pattern, extent of collaborative measure, influence of articles over the year and some other parameters too which are relevant with the objectives of this study.

Objectives of the study

- To identify the authorship pattern in digital library research in BRICS countries;
- To determine the magnitude of collaborative research;
- To find out the most prolific authors in digital library research; and
- To determine the impact of the articles.

Methodology

For the study, research done in digital libraries from the BRICS region are considered. The citation data was downloaded from the SCI-EXPANDED, SSCI, and A&HCI databases of the Web of Science platform**.** To retrieve the dataset for conducting the current study the following search strategy was used "TS= (Digital Libraries OR Electronic Libraries OR Virtual Libraries), refined by: COUNTRIES/REGIONS: (PEOPLES R CHINA OR RUSSIA OR INDIA OR BRAZIL OR SOUTH AFRICA), and timespan 2000-2019. . A total of 1220 records that were retrieved using the search query have been analysed.

Data analysis

Year-wise distribution and annual growth rate

Table 1 shows the year-wise distribution of the publication and annual growth rate (AGR). The highest number of publications was in the year 2019 (11.39%) followed by the year 2014 and 2018 with 8.52% of the total publication. The annual growth rate was highest in 2004 (125) followed by the year 2002 (107.69) while in 2005, 2006, 2011, 2015, and 2017, the AGR is negative.

Document-wise distribution

Table 2 reveals the types of documents. Out of 1220 publications, 948 (77.7%) publications are journal articles, followed by proceedings papers- 117 (9.59%), review papers- 99 (8.11%), book reviews- 35 (2.86%), and editorial material- 6 (0.49%).

Language-wise distribution

Table 3 shows the language-wise distribution of digital library research by BRICS countries and analysis resolved that English is the most favoured language to publish research papers and out of a total of 1220 publications, 94.42% of publications are in the English language. The second top language is Portuguese with 53 (4.34%) publication followed by Chinese (0.73%), Spanish (0.42%) and French (0.09%) publications.

Table 1 — Year-wise distribution and annual growth rate

Year	Total publication	Percentage	Annual growth rate
2000	12	0.98	--
2001	13	1.06	8.33
2002	27	2.21	107.69
2003	28	2.29	3.70
2004	63	5.16	125
2005	39	3.19	-38.09
2006	28	2.29	-28.20
2007	34	2.78	21.42
2008	42	3.44	23.52
2009	45	3.68	7.14
2010	58	4.75	28.88
2011	54	4.42	-6.89
2012	64	5.24	18.51
2013	79	6.47	23.43
2014	104	8.52	31.64
2015	98	8.03	-5.76
2016	102	8.36	4.08
2017	87	7.13	-14.71
2018	104	8.52	19.54
2019	139	11.39	33.65
Total	1220		

Authorship pattern

Table 4 shows majority of publications in digital library research are collaborative in nature. One hundred and fifty five papers were single authored papers, 225 were two-authored, 198 were two authored and 173 publication were four authored. There are 88 papers with 10 or more authors.

Collaboration pattern

The degree of collaboration (DC)[10], collaborative index (CI)[11], collaboration co-efficient (CC)[12] and modified collaborative co-efficient (MCC)[13] for each year is calculated and shown in Table 5.

The year 2016 has the highest DC (0.96), followed by the year 2011 having DC (0.94) and DC observed in the year 2007 having DC (0.61). The year 2014 has the highest CI (5.60) followed by the year 2019 having CI (5.50), whereas the lowest CI (2.42) was observed in the year 2008. The highest CCs (0.70) were observed in the years 2011 and 2015, followed by CCs (0.69) in the years 2012, 2013, and 2014. The lowest CC (0.41) was recorded in the year 2008. The highest MCCs (0.71) were in the years 2011 and 2015, followed by years 2012, 2014, 2016 having MCC (0.70). The lowest MCC (0.42) was observed in the year 2008. The overall value of the Degree of collaboration is 0.84, Collaborative Index is 4.14, the Collaboration co-efficient is 0.59 and the Modified collaboration co-efficient is 0.61 for all the years.

Table 2 — Types of documents wise distribution of digital library research

Document type	Publication	Percentage
Articles	948	77.70
Book review	35	2.86
Early access	5	0.40
News item	1	0.08
Proceedings paper	117	9.59
Editorial material	6	0.49
Letter	2	0.16
Software review	1	0.08
Review	99	8.11
Meeting abstract	6	0.49
Total	1220	

Table 3 — Language-wise distribution of digital library research

Language	Publication	Percentage
English	1152	94.42
Portuguese	53	4.34
Chinese	9	0.73
Spanish	5	0.42
French	1	0.09
Total	1220	100

Table 4—Authorship pattern in digital library research

Year	Number of authors											Total publication
	1	2	3	4	5	6	7	8	9	10	More than 10	
2000	2	5	0	2	1	2	0	0	0	0	0	12
2001	2	2	3	4	1	0	0	0	0	1	0	13
2002	5	8	5	4	4	0	0	1	0	0	0	27
2003	7	3	10	3	1	1	1	0	1	0	1	28
2004	15	13	17	9	4	4	0	1	0	0	0	63
2005	7	12	3	9	4	2	1	1	0	0	0	39
2006	10	1	4	6	1	3	1	1	0	1	0	28
2007	13	6	5	4	2	3	0	0	0	0	1	34
2008	14	14	3	7	2	1	1	0	0	0	0	42
2009	5	11	9	6	1	3	4	5	1	0	0	45
2010	6	13	6	10	9	3	3	2	1	0	5	58
2011	3	9	8	14	4	3	2	1	5	2	4	54
2012	5	8	12	9	10	6	4	1	5	1	3	64
2013	6	13	13	10	8	8	4	5	2	1	9	79
2014	8	16	16	9	19	5	6	8	5	3	9	104
2015	7	15	13	11	10	10	10	4	5	4	9	98
2016	4	20	21	14	12	8	8	4	3	2	6	102
2017	12	10	11	16	9	11	7	4	2	2	3	87
2018	11	23	17	12	13	14	3	5	1	2	3	104
2019	13	24	22	14	21	14	7	8	0	4	12	139
Total articles	155	225	198	173	136	101	62	51	31	23	65	1220

Table 5—Collaboration pattern

Year	Single-authored paper	Multi-authored paper	Total	DC	CI	CC	MCC
2000	2	10	12	0.83	3.08	0.53	0.58
2001	2	11	13	0.84	3.53	0.59	0.64
2002	5	22	27	0.81	2.96	0.53	0.55
2003	7	21	28	0.75	3.35	0.52	0.54
2004	15	48	63	0.76	2.85	0.50	0.51
2005	7	32	39	0.82	3.15	0.54	0.56
2006	10	18	28	0.64	3.42	0.48	0.50
2007	13	21	34	0.61	2.79	0.42	0.43
2008	14	28	42	0.66	2.42	0.41	0.42
2009	5	40	45	0.88	3.95	0.62	0.63
2010	6	52	58	0.89	4.55	0.64	0.65
2011	3	51	54	0.94	5.14	0.70	0.71
2012	5	59	64	0.92	4.87	0.69	0.70
2013	6	73	79	0.92	5.37	0.69	0.69
2014	8	96	104	0.92	5.60	0.69	0.70
2015	7	91	98	0.92	6.28	0.70	0.71
2016	4	98	102	0.96	4.95	0.69	0.70
2017	12	75	87	0.86	4.90	0.65	0.65
2018	11	93	104	0.89	4.22	0.63	0.64
2019	13	126	139	0.90	5.50	0.67	0.67
Total	155	1065	1220				
	Average			0.84	4.14	0.59	0.61

Co-authorship index (CAI)

Table 6 specifies the calculated values of the Co-authorship Index (CAI) for publications having single author, two-authors, three authors, four authors, and more than four authors, based on the formula given by Schubert and Braun (1986)[14]. The analysis resolved that the highest value of CAI for single authors is (300.94) in the year 2007 and the lowest is (30.86) in 2016. The highest CAI for two authored papers is (225.92) in the year 2000 and the lowest CAI (19.36) in the year 2006. In the case of triple authorship, the highest CAI (220.05) was observed in the year 2003 and the lowest CAI is 0 in the year 2000. In the case of four authors' papers, it was found that the highest CAI (216.98) in the year 2001 and lowest CAI (61.02) in 2014. In more than 4 authored papers highest CAI (13.02) was found in 2015 and the lowest CAI (24.77) in 2008.

Country-wise distribution

Fig. 1 shows the country-wise distribution of the publication in the area of digital research and it was found that China has contributed the highest number of papers with 690 (56.58%) publications, followed by India with 205 (16.80%), Brazil 197 (16.15%), South Africa 102 (8.37%) and Russia has 42 (3.45%) publications.

Citation impact-wise distribution

A citation shows the quantitative impact of an article as researchers cite relevant documents in their studies. The indicator citations per paper (CPP) is used to find out the impact of the articles. Table 7 shows the citation impact of the articles in which, the highest publication was found in the year 2019 (139), followed by 2014, 2018 having 104 publications and

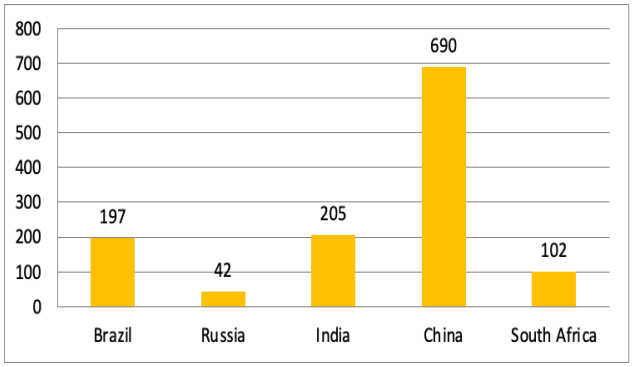

Fig. 1—Country-wise distribution of digital library research

Table 6 — Co-authorship index (CAI)

Years	Single-authored paper	CAI for 1 author	Two-authored paper	CAI for 2 author	Three-authored Paper	CAI for 3 authors	Four-authored paper	CAI for 4 authors	More than 4 authored Paper	CAI for More than 4 author	Total output
2000	2	131.18	5	225.92	0	0	2	117.53	3	65.03	12
2001	2	121.09	2	83.41	3	142.19	4	216.98	2	40.01	13
2002	5	145.75	8	160.65	5	114.10	4	104.47	5	48.17	27
2003	7	196.77	3	58.09	10	220.05	3	75.55	5	46.45	28
2004	15	187.40	13	111.88	17	166.26	9	100.74	9	37.16	63
2005	7	141.27	12	166.83	3	47.39	9	162.73	8	53.35	39
2006	10	281.10	1	19.36	4	88.02	6	151.11	7	65.03	28
2007	13	300.94	6	95.68	5	90.61	4	82.96	6	45.90	34
2008	14	262.36	14	180.74	3	44.01	7	117.57	4	24.77	42
2009	5	87.45	11	132.54	9	123.23	6	94.07	14	80.92	45
2010	6	81.42	13	121.53	6	63.74	10	121.56	23	103.15	58
2011	3	43.72	9	80.32	8	91.28	14	182.82	21	101.16	54
2012	5	61.49	8	67.77	12	115.53	9	99.18	30	121.93	64
2013	6	59.77	13	89.22	13	101.39	10	89.26	37	121.83	79
2014	8	60.54	16	83.4188	16	94.79	9	61.02	55	137.56	104
2015	7	56.22	15	82.99	13	81.72	11	79.15	52	138.02	98
2016	4	30.86	20	106.31	21	126.85	14	96.79	43	109.66	102
2017	12	108.56	10	62.32	11	77.90	16	129.69	38	113.61	87
2018	11	83.25	23	119.91	17	100.71	12	81.36	41	102.55	104
2019	13	73.61	24	93.62	22	97.52	14	71.02	66	123.51	139
Total	155		225		198		173		469		1220

in 2016 is 102. Total citation (TC) was found highest (1432) in the year 2012, followed by TC (1426) in the year 2011. Again, it was observed that the highest citations per paper (CPP) was (64.31) in the year 2001, followed by CPP (26.41) in the year 2011. The average CPP was 14.06 for the study period.

Top 10 organizations

Table 8 gives the top 10 leading organizations in the rank of their contribution in digital library research among BRICS countries. Chinese Academy of Science has the highest number of contributions with 68 (5.57%) publications, followed by Wuhan University- 58 (4.75%), Universidade De Sao Paulo- 43 (3.52%), Universidade Federal de Minas Gerais - 36 (2.95%) contributions. The IITs systems of India ranked at 10th position with 23 (1.85%) contributions out of 1220 publications.

Table 7 — Citation impact of digital library research publications

Year	TP	TC	CPP	
2000	12	81	6.75	
2001	13	836	64.31	
2002	27	317	11.74	
2003	28	257	9.18	
2004	63	434	6.89	
2005	39	211	5.41	
2006	28	295	10.54	
2007	34	613	18.03	
2008	42	362	8.62	
2009	45	621	13.8	
2010	58	1127	19.43	
2011	54	1426	26.41	
2012	64	1432	22.38	
2013	79	1095	13.86	
2014	104	1393	13.39	
2015	98	1269	12.95	
2016	102	868	8.51	
2017	87	394	4.53	
2018	104	322	3.1	
2019	139	191	1.37	
Total	1220	13544	Average CPP	14.06

(TP=Total publications, TC= Total Citation, CPP= Citation per paper).

Top 10 prolific authors

Table 9 shows the top 10 most prolific authors in digital library research in BRICS countries, it was found that Fourie I from South Africa has occupied the 1st ranked with 23 (1.88%) number of publications, Gonclaves M A from Brazil occupied 2nd position with 18 (1.47%) publications and Zhang Y from China with 17 (1.39%) publications occupied 3rd position out of 1220 articles.

Appropriateness of Lotka's Law

Table 10 depicts the productivity of the researchers in Digital Library literature, and it is tested to find whether it will follow Lotka's law[15]. To verify

Table 8 —Top 10 organizations contribution

Sl. no.	Organization	Paper	Percentage
1	Chinese Academy of Sciences	68	5.57
2	Wuhan University	58	4.75
3	Universidade de Sao Paulo	43	3.52
4	Universidade Federal de Minas Gerais	36	2.95
5	Zhejiang University	35	2.86
6	Peking University	34	2.78
7	University of Pretoria	33	2.70
8	Shanghai Jiao Tong University	30	2.45
9	National Astronomical Observatory CAS	24	1.96
10	Indian Institute of Technology System IIT System	23	1.85

Table 9 — Top 10 prolific authors

Sl. no.	Authors	Country	Paper	Percentage
1	Fourie I	South Africa	23	1.88
2	Gonclaves M A	Brazil	18	1.47
3	Zhang Y	China	17	1.39
4	Laender A H F	Brazil	15	1.23
5	Li J	China	14	1.14
6	Wang J	China	14	1.14
7	Zha X J	China	14	1.14
8	Wang H	China	13	1.06
9	Wang Y	China	13	1.06
10	Yan Y L	China	12	0.98

Table 10 — Appropriateness of Lotka's Law

No. of papers (x)	No. of Observed authors(fo)	No. of expected authors (fe)	fo-fe	$(fo-fe)^2$	$(fo-fe)^2/fe$
1	155	155	0	0	0
2	225	107	118	13924	131
3	198	86	112	12544	146
4	173	73	100	10000	136
5	136	65	71	5041	78
6	101	59	42	1764	30
7	62	54	8	64	1
8	51	50	1	1	0
9	31	47	-16	256	5
10	23	45	-22	484	11
11	65	42	23	529	12
		Chi-square (χ^2)			551

whether the author's productivity frequency sustains Lotka's law, the Chi-square test is applied to the data set. The Chi-square test for observed and hypothetical authors are calculated.

C = 155

n = 0.54

To get the Chi-Square value, calculating the sum of all the differences between the square of observed and expected frequency (fo-fe)2 and dividing it by the expected frequency i.e. (fo-fe)2/fe. The Chi-Square value obtained is 551, which is highly significant and greater than the expected value of 4.64 at a 5% level of significance. It is found that the law is not in conformity with the present data set.

Findings

This study examined 1220 publications on digital library research in BRICS countries from 2000 to 2019. It is found that publications increased during the later period in comparison to the earlier period of the study. Journal articles are the most common document form of published literature on digital library. Though there is variation in expressing the research work in different languages like Portuguese, Chinese, Spanish but maximum numbers of articles are in English language.

The increasing values of collaboration co-efficient and co-authorship index value and analysis of the collaborative behaviour of authors in digital library research implies that collaborative research work is common in this area. China, known as the technological workshop of the world, is the top contributor of digital library research literature among BRICS countries.

Chinese Academy of Sciences is the most productive organization, and it is worth mentioning that Indian IIT System ranks in the 10th position as per analysis of most productive organization is considered. Lotka's Law of author productivity is also implemented on the raw data extracted and unfortunately the Chi-Square value obtained is found to be greater than the expected at a 5% significant level which explicitly denies the good-ness-of-fit of the Lotka's law into the data.

Conclusion

The scientometric tools are used to measure the scientific productivity of a country or an institution. The research productivity of developing countries is not comparable with developed countries. But latest trend shows a progressive swing to the developing countries mainly BRICS countries. It is obvious from the analysis that India and China are working on the research on digital library Research output and if they can sustain this trend, they can emerge as the top contributor in the globe in the upcoming days. Russia and South Africa can raise their contribution in the field of digital library research. This study is helpful to understand the publication pattern of contributions in the field of digital library and it is a basis to recognise the current scenario of the literature of digital library published in BRICS countries.

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