Asian Journal of Information Science and Technology
ISSN: 2231-6108 (P) Vol.9 No.1, 2019, pp.1-7

DOI: https://doi.org/10.51983/ajist-2019.9.1.2610

Application of Bradford's Law of Scattering to the Economics Literature of India and China: A Comparative Study

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(Received 1 December 2018; Revised 23 December 2018; Accepted 30 December 2018; Available online 4 February 2019)

Abstract **- This paper deals with the applicability of Bradford law of scattering of the publications of India and China. The data for the study collected from WOS database, 887 journals publishing 1924 economics subject publications from India and 1627 journals published 4427 Chinese economics publications. The ranked list of journals prepared for both the datasets and the applicability of Bradford's law was tested. The journals distribution pattern of the economics literature fit Bradford's distribution pattern. The applicability of Egghe's model (modification of Leimkuhler's model) was also tested and found valid for both the datasets.**

Keywords: **Bradford's Law, Leimkuhler's Model, Egghe's Model, Economics, India, China**

I. INTRODUCTION

Scientific journals are the significant primary sources of information which communicate the nascent, original research findings and new ideas developed by the scientists through the research articles to the fellow researchers in the chosen field of interest and helps in subsequently kindling the new ideas for further research. Journals identify and forecast of existing new concepts, approaches, techniques and growth and developments in the subject in order to keep the researchers well informed. Studies have shown that research output in a subject field concentrated in a few selected journals, regarded as core journals because of the similarity of the association of ideas between the subject of journals and areas of research work.

The idea of core journals was first identified by S C Bradford in 1934. There are other techniques to find out the core journals in the subject field, such as citation indexing technique, impact factor value of journals etc. These techniques made convenient for the libraries to identify core journals in a given subject field out of a large number of journals. The other factors like increasing the cost of journals, dwindling library budgets and many other challenges continuously bother libraries. Bradford's technique is the most popular in bibliometric studies with suitable mathematical evidence.

Bradford's law explains how the research articles on any given subject field scattered or spread across different journals. It was first reported in 1934 in the journal Engineering by Bradford and, subsequently, in a book titled Documentation by the same author in 1948 where the verbal formulation and graphical representation of his law are explained. The present paper examines the application of Bradford's law to the economics literature published by India and Chinese scholars during 1991-2016.

II. OBJECTIVES OF THE STUDY

1. To prepare the rank list of journals and study the phenomenon for the scattering of journals in India and Chinese economics publications.
2. To verify Bradford's law of scattering to economics literature.

III. METHODOLOGY

The present study focused on the verification of Bradford's law of scattering to the research outcome of Indian and Chinese economics research output published during 1991-2016. The data for this study was collected from the Web of Knowledge portal, a comprehensive citation indexing database containing databases sciences, social sciences and arts and humanities. The query was designed by refereeing the various topics in the subject and the country. The data was downloaded, which include 1924 publications appeared in 887 journals contributed by Indian scholars, and 1620 journals contributed 4427 research articles by Chinese scholars. The study identified the journals and their corresponding frequency of articles for the verification of Bradford's law of scattering suggested by Bradford and Egghe's model i.e. modification of the Leimkuhler's model (Wardikar, 2013), (Savanur & Hullolli, 2018).

IV. RESULTS AND DISCUSSION

A. Publication Productivity

Analyzing and quantifying the process of scientific knowledge production in different subjects is an interest to scientometrics. The scientific productivity of countries refers to the increase of research activities in terms of research output in different forms and languages over a period of time. Scientometric studies on the growth of publications regarded as the most objective and reliable method of assessment.

TABLE I YEAR-WISE CONTRIBUTION OF INDIA AND CHINA PUBLICATIONS IN THE FIELD OF ECONOMICS

Year	India			China		
	Articles India	Cum-Articles	%	Articles-China	Cum-Articles	%
1991	14	14	0.73	0	0	0.00
1992	21	35	1.09	0	0	0.00
1993	27	62	1.40	4	4	0.09
1994	17	79	0.88	7	11	0.16
1995	31	110	1.61	11	22	0.25
1996	34	144	1.77	9	31	0.20
1997	22	166	1.14	11	42	0.25
1998	27	193	1.40	17	59	0.38
1999	27	220	1.40	23	82	0.52
2000	44	264	2.29	39	121	0.88
2001	45	309	2.34	50	171	1.13
2002	43	352	2.23	65	236	1.47
2003	37	389	1.92	58	294	1.31
2004	39	428	2.03	79	373	1.78
2005	43	471	2.23	73	446	1.65
2006	47	518	2.44	94	540	2.12
2007	79	597	4.11	112	652	2.53
2008	78	675	4.05	145	797	3.28
2009	97	772	5.04	208	1005	4.70
2010	68	840	3.53	247	1252	5.58
2011	99	939	5.15	302	1554	6.82
2012	127	1066	6.60	346	1900	7.82
2013	147	1213	7.64	413	2313	9.33
2014	154	1367	8.00	520	2833	11.75
2015	268	1635	13.93	720	3553	16.26
2016	289	1924	15.02	874	4427	19.74

The year-wise growth of a number of publications by India and China is tabulated in table I and the depicted in the figure-1.

There are 1924 publications published by the Indian scholars in the field of economics during 1991-2016 with an average of 74 papers per year. The year 2016 witnessed the most productive year having (15 %) papers published, followed by (14%) in the year 2015 and (8%) papers in 2014. The data shows steady growth of publications during the period of study. Similarly, there were 4427 publications by Chinese scholars during 1991-2016 with an average of 170 publications per year.

The year 2016 witnessed the most productive year with 20% of the total papers, followed by (16%) in 2015 and 12% papers in 2014. It can be noticed from the figure-1 that the Chinese publications grew at a steady rate and during 2008 onwards the growth of publications shows steep high as compared to Indian publications.

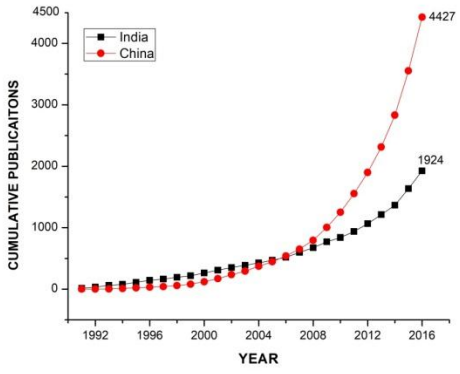

Fig. 1 Publication productivity of Economics research

B. Ranked List of Journals in Economics Literature

The ranked list of journals publishing Economics literature by Indian Scholar is tabulated in the Table II . The total 887 journal ranks were awarded, all these journals published as

many as 1924 articles in economics subject during 1991-2016. Among these journals, Indian Journal of Agronomy tops the journal ranking list by publishing the highest number of articles 94 (4.89%), followed by Indian Journal of Agricultural Sciences 91 (4.73%) articles and Renewable & Sustainable Energy Reviews occupied the third rank with 28 (1.46%). Two journals Current Science and Indian Journal of Animal Sciences with 27 (1.4%) articles respectively took the fourth rank and Research on Crops 21 (1.09%) the fifth rank, and so on.

The top five ranked journals in the ranked list contributed to nearly 15% of the total articles and the five journals contributed are not even 1% of the total number of journals. The research output of economics by Indian scholars was not concentrated on a small set of nucleus or core journals. In other words, a large number of Indian economics research articles 1250 (65%) are scattered over across 840 (95%) a large number of journals. These journals are of multidisciplinary subjects in social sciences and agricultural sciences.

This clearly indicates that probably there is less number of journals devoted to the economics subjects and hence the research scholars tend to publish their research work in multi-disciplinary journals.

TABLE II RANKING OF JOURNALS PUBLISHING ECONOMICS LITERATURE BY INDIA

INDIA						
S. No.	**Journal**	**Total Publication**	**Percentage**	**Total Citations**	**Percentage**	**ACPP**
1	Indian Journal of Agronomy	94	4.89	252	1.13	2.68
2	Indian Journal of Agricultural Sciences	91	4.73	138	0.62	1.52
3	Renewable & Sustainable Energy Reviews	28	1.46	1394	6.27	49.79
4	Current Science	27	1.40	251	1.13	9.30
5	Indian Journal Of Animal Sciences	27	1.40	62	0.28	2.30
6	Research on Crops	21	1.09	4	0.02	0.19
7	Energy Policy	20	1.04	521	2.34	26.05
8	Indian Journal Of Economics & Development	17	0.88	5	0.02	0.29
9	PLOS One	17	0.88	313	1.41	18.41
10	Journal of Evolution of Medical & Dental Sciences-Jemds	16	0.83	0	0.00	0.00
11	Legume Research	16	0.83	5	0.02	0.31
12	Man In India	16	0.83	19	0.09	1.19
13	Pacific Business Review International	15	0.78	1	0.00	0.07
14	International Journal of Agricultural And Statistical Sciences	13	0.68	1	0.00	0.08
15	Range Management & Agroforestry	13	0.68	12	0.05	0.92
16	Ama-Agricultural Mechanization In Asia Africa And Latin America	11	0.57	4	0.02	0.36
17	Ecological Economics	11	0.57	359	1.61	32.64
18	Economic Modelling	11	0.57	89	0.40	8.09
19	Social Science & Medicine	11	0.57	247	1.11	22.45
20	World Development	11	0.57	140	0.63	12.73
21	Journal of Scientific & Industrial Research	10	0.52	149	0.67	14.90
22	26 Journals (Publication within the range of 9-6)	178	9.25	3382	15.21	19.00
23	840 Journals (Publication within the range of 5-1)	1250	64.97	14886	66.95	11.91
		1924		22234		
ACPP: Average Citations Per Paper						

Table III lists the ranking of journals publishing economics literature by Chinese scholars. The total of 1620 journals publishing 4427 various types of documents in economics subject during 1991-2016.

TABLE III RANKING OF JOURNALS PUBLISHING ECONOMICS LITERATURE BY CHINA

CHINA						
S. No.	**Journal**	**Total Publication**	**Percentage**	**Total Citations**	**Percentage**	**ACPP**
1	Energy Policy	67	1.51	2276	3.47	33.97
2	China Economic Review	66	1.49	914	1.39	13.85
3	Journal of Comparative Economics	65	1.47	1467	2.24	22.57
4	Journal of Cleaner Production	56	1.26	918	1.40	16.39
5	Sustainability	55	1.24	188	0.29	3.42
6	PLOS One	54	1.22	587	0.90	10.87
7	China & World Economy	40	0.90	261	0.40	6.53
8	Economic Modelling	38	0.86	139	0.21	3.66
9	Renewable & Sustainable Energy Reviews	38	0.86	1206	1.84	31.74
10	Habitat International	36	0.81	441	0.67	12.25
11	Journal of Banking & Finance	34	0.77	838	1.28	24.65
12	Applied Energy	33	0.75	755	1.15	22.88
13	China Agricultural Economic Review	30	0.68	131	0.20	4.37
14	International Review of Economics & Finance	27	0.61	136	0.21	5.04
15	Physica A-Statistical Mechanics & Its Applicatns	27	0.61	243	0.37	9.00
16	Energy	26	0.59	479	0.73	18.42
17	Land Use Policy	26	0.59	366	0.56	14.08
18	Journal Of Geographical Sciences	25	0.56	166	0.25	6.64
19	Journal of International Economics	24	0.54	342	0.52	14.25
20	Journal of Econometrics	23	0.52	232	0.35	10.09
21	Journal of Contemporary China	22	0.50	72	0.11	3.27
22	Chinese Geographical Science	21	0.47	103	0.16	4.90
23	Applied Economics	19	0.43	85	0.13	4.47
24	European Journal of Operational Research	19	0.43	349	0.53	18.37
25	Emerging Markets Finance And Trade	18	0.41	50	0.08	2.78
26	Review of International Economics	18	0.41	57	0.09	3.17
27	Social Science & Medicine	18	0.41	622	0.95	34.56
28	International Journal of Production Economics	17	0.38	183	0.28	10.76
29	Review of Development Economics	17	0.38	35	0.05	2.06
30	38 Journals (Publication within the range of 16-11)	477	10.77	8536	13.02	17.90
31	1553 Journals (Publication within the range of 10-1)	2991	67.56	43382	66.17	14.50
		4427		65559		
ACPP: Average Citations Per Paper						

Among these journals Energy Policy tops the journal ranking list publishing 67 (1.51%) articles, followed by Chinese Economic Review publishing 66 (1.49%) articles and Journal of Comparative Economics occupied the third position with 65 (1.47%) articles. The Journal of Cleaner Production with 56 (1.26%) articles and Sustainability with 55 (1.24%) articles with fourth and fifth rank respectively.
The analysis shows that the research work on economics in China is scattered in various journals and not concentrated on the few core or nucleus journals.

We observe a similar trend among the scholar in publishing research output in economics in India and China. The top ten ranked journals in the ranked list contributed to 12% of the total literature and the top-ranked ten journals contributed not even 1% of the total number of journals. The majority of the publications 2991 (68%) (published in the range of 1-10 articles each) are scattered across large number 1553 (96%) of journals.

This clearly indicates that probably there is less number of journals devoted to the economics subjects and hence the

research scholars tend to publish their research work in multi-disciplinary journals.

C. Bradford's Law of Scattering

Identifying the journals in a subject field is an important aspect of scientometric studies especially Bradford's law of scattering, has its application in the acquisition policy of journals in libraries and information centres.

Bradford law of scattering describes how the literature on a particular subject is scattered or distributed in various journals, and he formulated that, "if a scientific journals are arranged in order of decreasing productivity of articles on a given subject, they may be divided into a nucleus of periodicals more particularly devoted to the subject and several groups or zones containing the same number of articles as the nucleus. When the number of periodicals in the nucleus in the and succeeding zones will be as *1: n : n²*" where *n* is a multiplier (Bradford, 1934, p.86).

Bradford gave a graphical model for his law. The mathematical models were suggested later by Vickery (1948), Leimkuhler (1967), Brookes (1969a, 1969b), Wilkinson (1972), Egghe (1985, 1986, 1990a, 1990b), Basu (1992), Ravichandra Rao (1998). These scholars gave the mathematical models for the scattering of articles in journals are mentioned here (Sudhier, 2010).

D. Brooke's Model (1969)

$$F(x) = a + b \log x \qquad (1)$$

where *F(x)* is the cumulative number of references contained in the first *x* most productive journals, and *a* and *b* are constants. This is the most widely used formulation of Bradford's Law.

Vickery (1948) extended the verbal formulation to show that it can be applied to any number of zones of equal yield.

E. Leimkulher's (1967) Model

$$R(r) = a \log(1 + br) \qquad (2)$$

where *R (r)* is the cumulative number of articles contributed by journals ranked 1 through *r*, and *a* and *b* are parameters. Where *r = 1, 2, 3 ….*

F. Egghe's model (1985, 1986) Modifications for Calculating Bradford's Multiplier based on Leimkuhler's Model

$$k = (e^{\gamma} \times Y_m)^{1/p} \qquad (3)$$

Where γ is Euler's number ($e^{\gamma} = 1.781$) , p = Number of zones i.e. 3.
y_m = Number of items in the most productivity sources.

r_0 = Number of journals in the nucleus zone of Bradford is calculated as:

$$r_0 = \frac{T\,(k-1)}{(k^p - 1)} \qquad (4)$$

where T = Total number of journals

G. Application of Bradford's Law

1. India

Table III presents details of the articles published by the Indian scholars in the field of Economics. Furthermore, the frequency of journal articles arranged in decreasing order of the articles to test Bradford's law.

For testing of the verbal formulation of Bradford's law, the 887 journal titles were divided into three zones. The distribution of journals and a corresponding number of articles in the three zones along with the value of Bradford multiplier are shown in Table IV.

In the present dataset, the first 42 journals publishing 644 articles, followed by 229 journals containing 641 articles and next 616 journals containing 639 articles. It can be noticed that the three zones are almost exactly the 1/3rd of the total articles as suggested by Bradford.

TABLE IV SCATTERING OF JOURNALS AND ARTICLES OVER BRADFORD ZONE

Zone	Journals	Articles	Bradford Multiplier
1st	42	644	---
2nd	229	641	5.4
3rd	616	639	2.6
Total	887	1924	Avg. 4

The identified zones arranged in the geometric series in the form of *1: n: n²* as given by Bradford. We found that the relationship of each zone in the present study is 42:168:672.

Here, 42 journals found in the nucleus zone and the mean value of Bradford's multiplier is n=4. Therefore, 42 : (42 x 4) : (42 x 4^2) :: 1 : n : n^2
42: 168: 672
Since the percentage of error is negative here, the data fits well Bradford's law.

H. Application of Egghe's Model

Though the dataset fits into Bradford's model, to compare the Egghe's model i.e. modification of Leimkuhler is employed for the verification of Bradford's law of scattering. For the application of Bradford's law, three zones were selected, p=3, $y_m = 74$. Then by using mathematical formula (3), the obtained value of the Bradford's multiplier *k* is 5.51. The number of articles in each zone is y_o = 641.33.

The r_0 = number of journals in the nucleus of Bradford is calculated using the equation (4) and hence $r_0 = 24.05$

The No. of Journals in the nucleus zone is 24, similarly, the number of journals in the second the third zones are 132.51 and 730 respectively. Therefore, the distribution is written as:
$24.05 : (24.05X5.51) : (24.05 \times 5.51^2) :: 1 : k : k^2$
i.e. 24.05 : 132.51 : 730.16

TABLE V SCATTERING OF JOURNALS AND ARTICLES OVER BRADFORD ZONE

Zone	No. of Journals	No. of Articles	Bradford Multiplier
1st	24.05	522	---
2nd	132.51	533	5.5
3rd	730.16	869	5.5
Total	887	1924	

From the above table, it's clear that the journals contributing articles to each zone increase by multiplier 5.5. Top 24 journals appeared in the nucleus zone contributed 522 articles, followed by 132.51 approx. 133 journals in the second zone containing 533 articles and 730 journals with 869 articles in the third zone. Since the percentage of error is very negligible, Bradford's law fits very well in this data set.

1. China

The ranked list of journals and the corresponding frequency of articles published by Chinese scholars in the field of Economics is shown in Table IV.

For the verification of verbal formulation of Bradford's law, the 1620 journal titles published 4427 articles were divided into three zones. The table VI provides the zone-wise journals and their corresponding articles along with the Bradford multiplier.

TABLE VI SCATTERING OF JOURNALS AND ARTICLES OVER BRADFORD ZONE

Zone	No. of Journals	No. of Articles	Bradford Multiplier
1st	71	1476	---
2nd	329	1476	4.6
3rd	1220	1475	3.7
Total	1670	4427	Avg. 4.17

In the present dataset, the top 71 journals publishing 1476 articles in the nucleus zone, followed by 329 journals containing 1476 articles second zone and 1220 journals containing 1475 articles in the third zone. The mean value of Bradford's multiplier is n=4.17. It can be noticed that the three zones are almost exactly the 1/3rd of the total articles as suggested by Bradford.

The identified zones arranged in the geometric series in the form of *1: n: n^2* as given by Bradford. We found that the relationship of each zone in the present study is *71 : 294.65 : 1222.79*. Since the percentage of error is (-1.94) negligible here, the data fits well Bradford's law.

I. Application of Egghe's model

Here also, though the dataset fits into Bradford's model, to compare the scattering of journals in the different zones, the Egghe's model i.e. modification of Leimkuhler is employed. Total articles were equal-divided into three zones (p=3) is y_o = 641.33. $y_m = 67$. Then by using mathematical formula (3) and (4), the obtained value of the Bradford's multiplier and number of journals in the nucleus zone were *k* = 4.9231 and $r_0 = 24.05$ respectively.

The No. of Journals in the nucleus zone is 53.71, followed by, the number of journals in the second the third zones are 264.41 and 1301.76 respectively. Therefore, the distribution is written as:
$53.71: (53.71 \times 4.92) : (53.71 \times 4.92^2) :: 1 : k : k^2$
i.e. 53.71 :264.241 : 1302.76

TABLE VII SCATTERING OF JOURNALS AND ARTICLES OVER BRADFORD ZONE

Zone	No. of Journals	No. of Articles	Bradford Multiplier
1st	53.71	1292	---
2nd	264.41	1424	4.9231
3rd	1301.76	1711	4.9231
Total	1620	4427	

From the above table, it's clear that the journals contributing articles to each zone increase by multiplier 4.9231. Top 54 journals appeared in the nucleus zone contributed 1292 articles, followed by 264 journals in the second zone containing 1424 articles and 1302 journals with 1711 articles in the third zone. Since the percentage of error is very negligible, Bradford's law fits very well in this data set.

V. CONCLUSION

The journal distribution pattern of the Economics literature published during 1991-2016 from India and China countries fit the Bradford distribution pattern. Similarly when the Egghe's model applied for the same data set for the verification of Bradford's law and found that both the data sets fit Bradford's distribution pattern with the unequal number of articles in the three zones. The data also revealed that majority of the economics research publications of both the countries scattered across various journals of multi-disciplinary nature mostly in social sciences and agricultural sciences. In other words, both India and Chinese economics publications not concentrated much in core or nucleus journals in economics.

ACKNOWLEDGEMENT

The author conveys sincere thanks to Indian Council of Social Science Research (ICSSR), New Delhi for providing financial support through Project titled "Scientometric Analysis of Research Output in the field of Economics among BRICS countries: A Study".

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