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Authorship patterns in international business literature: applicability of Lotka's Law

Shehbaz Husain Naqvi[a] and Nishat Fatima[b]

[a]Assistant Professor, Dr. Zakir Husain Library, Jamia Millia Islamia, New Delhi-110025, E-mail: shnaqvi@jmi.ac.in
[b]Assistant Librarian, High Court of Delhi-Delhi-110003. E-mail: nishat.siddique@ymail.com

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The paper studies the applicability of Lotka's law for international business literature. The data included eleven thousand two hundred two (11202) references appended to research articles published in *Journal of World Business* during 2012-2014. It was found that Lotka's distribution is applicable to international business literature which was further conformed by using Chi square and K-S statistics tests.

Keywords: Lotka's Law; Author productivity; International Business; Straight Count Method; Chi-Square Test; K-S Test

Introduction

Lotka's law is one of the fundamental laws of bibliometrics. In 1926, Lotka[1] proposed his inverse square law correlating contribution of scientific papers to their number of contributions. The law provided fundamental theoretical base for bibliometric studies involving authorships. According to the law, the number of authors making *n* contributions is about $1/n^2$ of those making one; and the proportion of all contributors, that make a single contribution, is about 60percent.

Lotka deduced a general equation for the relation between the frequency distribution 'y' of persons making 'x' contributions as $X^n y = c$, constant and for the special case n = 2, the constant is 0.6079. The applicability of Lotka's Law in different disciplines has been studied. The present study test's the applicability of Lotka's law for literature on international business.

Review of literature

A number of studies have been carried out in the past to validate the Lotka's law. A few of them conform to Lotka's Law in a particular field, while others either partially or do not conform to Lotka's Law. Few of the recent studies that study the applicability of Lotka's Law in a particular subject area are discussed below.

A study was conducted by Singh and Rana[2] to conform applicability of Lotka's Law in the Gandhian literature. The data was collected from periodical articles related to Mahatma Gandhi published in English language up to 2010. In this study it was found that the Lotka's Law holds good in Gandhian Literature for the particular data set. Another study by Kumar[3] on Human Computer Interaction (HCI) also confirms that Lotka's Law is applicable in the field. The study is based on data collected from SCI for the period 2006-2011.

Shukla, Saxena and Riswadkar[4] studied Lotka's Law in the context of bio-energy literature published during 1982-1986 and found that Lotka's Law holds good for bio-energy literature. Study conducted by Schorr[5] conformed the validity of Lotka's Law in map librarianship. Nath and Jackson[6] also confirmed the applicability of generalized version of Lotka's Law in the field of management information systems.

A few studies partially conformed to the applicability of Lotka's Law in a particular field. Nishtha's study[7] on the publication patterns of PRL scientists for the period 1997-2006 found that Lotka's law is partially applicable in his study. Rajgoli and

Laxminarsaiah[8] also partially conformed the applicability of Lotka's law in spacecraft technology literature. Radhakrishnan and Kernizan[9] also found some deviations in applications of Lotka's Law in computer science literature.

Mini Devi[10] found that Lotka' Law is not applicable to toxicology literature. The data for her study was collected from TOXLINE database. Sudhier[11] in his paper on authorship pattern in physics literature examined the validity of Lotka's Law on the journal citations in the doctoral theses of University of Kerala, Thiruvananthapuram. Data set for this study consisted of 1,665 authors in straight count method and 3,367 authors through complete count method and the validity of Lotka's Law was determined through K-S statistical test and Chi-square test. The study concluded that Lotka's Law was not applicable in physics literature.

Another study conducted by Swain[12] on the publication pattern of *Library Philosophy and Practice*, a peer reviewed e-journal in the field of library & information science also concluded that Lotka's law is not applicable in the study.

Objectives of the study

i) To examine the validity of Lotka's Law in the field of international business;

ii) To apply Chi-square test for the conformity of Lotka's law to the said field; and

iii) To validate the study by using K-S test.

Methodology

Data for the study were collected in the form of the citations appended to the research articles in Elsevier's *Journal of World Business*. Analysis was conducted on 11,202 unique citations found in the research articles of *Journal of World Business* for 2012-2014 using MS-Excel.

Analysis

The simplest form to represent Lotka's Law is

$x^nXy= c$ (Equation 1)

Where x is number of contribution,

y is number of authors; and

c is a constant.

Determination of value of 'c' and 'n'

The values of 'c' and 'n' are calculated by using Lotka's equation "$x^nXy = c$". Data from Table 1 is used for calculating the values of 'n' and 'c'.

When the values of (x) and (y), as given in the row 1 of the Table 1, are inserted in Equation 1, we get:

$1^nX\ 4879=c$

$c =4879$

When data from second row of Table 1 is used in Equation 1, we get:

$2^nX\ 891=4879$

$2^n= 4879/891$

$2^n= 5.47587$

Taking log at both sides

$n \log2= \log(5.47587)$

$n\ (0.301)=0.738453$

$n=2.4533$

$n= 2.45$

Verification of Lotka's Law

From data analysis it was found that 4879 authors have contributed only 1 research article each, 891 authors have contributed 2 research articles, 365 authors have contributed three research articles and so on. It was found that out of 11202 citations, only one author has contributed 46 research articles. Expected number of authors was calculated at n = 2.45 & n = 2.46. It was found that in both the cases (at n = 2.45 and n= 2.46) there is not much variation between the observed and expected number of authors.

From the above calculations it can be said that Lotka's law is applicable to the present study. Table 1 shows the observed and expected number of authors in the field of international business using n = 2.45 & n = 2.46.

Goodness of fit tests

There are number of statistical tests that can be used to study goodness of fit. However, Chi-square test and Kolmogrov-Smirnov (K-S) test are commonly used test for this purpose.

Chi-square Test

The Chi-square test is used to find whether a theoretical distribution such as Lotka's Law fits the

Table 1—Observed and expected number of authors

Number of Contributions (x)	Number of Authors (y) [Observed]	Number of Authors (y) [Expected] at n = 2.45	Number of Authors (y) [Expected] at n =2.46
1	4879	4879	4879
2	891	893	887
3	365	331	327
4	183	163	161
5	105	95	93
6	68	61	59
7	35	41	41
8	34	30	29
9	24	22	22
10	13	17	17
11	16	14	13
12	6	11	11
13	6	9	9
14	5	8	7
15	1	6	6
16	4	5	5
17	1	5	5
18	1	4	4
19	2	4	3
20	2	3	3
21	1	3	3
22	1	3	2
23	3	2	2
28	2	1	1
30	1	1	1
42	1	1	0
44	1	0	0
46	1	0	0

given observations satisfactorily or not on the basis of certain hypotheses or theoretical considerations. If the observed values differ significantly from expected values then the goodness of fit test fails and it is said that null hypotheses is rejected.

Kolmogrov-Smirnov (K-S) Test

The test is conducted by finding the theoretical/expected cumulative frequency on the basis of null hypothesis [F(x)] and comparing it with the observed cumulative frequency [Sn(x)]. Then maximum deviation point (D), the point where the theoretical/expected and observed values show the maximum deviation is found and compared with the critical value. The null hypothesis is rejected if the calculated value of D is greater than critical value; otherwise not.

Chi square test on author's productivity

Table 2 shows the results of Chi square test on productivity of authors in relation to Lotka's Law (when expected authors was calculated by using n=2.45). Chi-Square test was calculated at a degree of freedom 10, and level of significance of 0.05 percent. The critical value at 0.05 percent significance level is 30.34,whereas Chi square value from the Chi Table is 18.307. The calculated value is significantly higher than the actual Chi value hence it can be said that Lotka's law is not applicable to this data set.

Table 3 shows the result of Chi-Square test on productivity of authors in relation to Lotka's Law (when expected authors was calculated by using n=2.46). Chi-Square test was calculated at a degree of freedom 10, and level of significance of 0.05 percent.

Table 2—Chi-Square test on observed and expected distribution of authors (when expected authors was calculated by using n=2.45)

No. of articles	Observed no. of citations (Fi)	Expected no. of authors (Pi)	Fi-Pi	$(Fi-Pi)^2$	$(Fi-Pi)^2/Pi$
1	4879	4879	0	0	0.00
2	891	893	-2	4	0.00
3	365	331	34	1156	3.49
4	183	163	20	400	2.45
5	105	95	10	100	1.05
6	68	61	7	49	0.80
7	35	41	-6	36	0.88
8	34	30	4	16	0.53
9	24	22	2	4	0.18
10	13	17	-4	16	0.94
11	16	14	2	4	0.29
12	6	11	-5	25	2.27
13	6	9	-3	9	1.00
14	5	8	-3	9	1.13
15	1	6	-5	25	4.17
16	4	5	-1	1	0.20
17	1	5	-4	16	3.20
18	1	4	-3	9	2.25
19	2	4	-2	4	1.00
20	2	3	-1	1	0.33
21	1	3	-2	4	1.33
22	1	3	-2	4	1.33
23	3	2	1	1	0.50
28	2	1	1	1	1.00
30	1	1	0	0	0.00
42	1	1	0	0	0.00
44	1	0	1	1	0.00
46	1	0	1	1	0.00
	466				$X^2 = 30.34$

Table 3—Chi-Square test on observed and expected distribution of authors (when expected authors was calculated atn=2.46)

No. of articles	Observed no. of citations (Fi)	Expected no. of authors (Pi)	Fi-Pi	$(Fi-Pi)^2$	$(Fi-Pi)^2/Pi$
1	4879	4879	0	0	0.00
2	891	887	4	16	0.02
3	365	327	38	1444	4.42
4	183	161	22	484	3.01
5	105	93	12	144	1.55
6	68	59	9	81	1.37
7	35	41	-6	36	0.88
8	34	29	5	25	0.86
9	24	22	2	4	0.18
10	13	17	-4	16	0.94
11	16	13	3	9	0.69
12	6	11	-5	25	2.27
13	6	9	-3	9	1.00
14	5	7	-2	4	0.57
15	1	6	-5	25	4.17

Contd—

Table 3—Chi-Square test on observed and expected distribution of authors (when expected authors was calculated atn=2.46)
—*Contd*

No. of articles	Observed no. of citations (Fi)	Expected no. of authors (Pi)	Fi-Pi	$(Fi-Pi)^2$	$(Fi-Pi)^2/Pi$
16	4	5	-1	1	0.20
17	1	5	-4	16	3.20
18	1	4	-3	9	2.25
19	2	3	-1	1	0.33
20	2	3	-1	1	0.33
21	1	3	-2	4	1.33
22	1	2	-1	1	0.50
23	3	2	1	1	0.50
28	2	1	1	1	1.00
30	1	1	0	0	0.00
42	1	0	1	1	0.00
44	1	0	1	1	0.00
46	1	0	1	1	0.00
	466				$X^2=31.58$

The critical value at 0.05 percent significance level is 31.58, whereas Chi square value from the Chi Table is 18.307. In this case also the calculated value is significantly higher than the actual Chi value,therefore it can again be concluded that Lotka's law is not applicable to this data set.

Kolmogrov-Smirnov (K- S) Test

To confirm results derived from Chi Square tests, we conducted K-S test on the data. Values of expected authors were calculated by using n = 2.45 and 2.46. The analysis shows that in both cases of n, data fits Lotka's distribution.

In the first step, we calculated Maximum deviation ($D_{max.}$) in case where expected number of authors were derived by using n=2.45. It's value is found to be 0.0055. The critical value of D in K-S test at 5 % level of significance is 0.565. While comparing the actual value of D, 0.00.55 with critical value 0.565, it is found that the actual value of D falls within the critical value of D. Therefore, it can be said that Lotka's law fits the author productivity distribution in this data set. The details are shown in Table 4.

In second step we calculated Maximum deviation ($D_{max.}$) in case where expected number of authors were derived by using n=2.46. It's value in this case is found to be 0.0076. The critical value of D in K-S test at 5 % level of significance is 0.565. While comparing the actual value of D, 0.0076 with critical value 0.565, it is found that the actual value of D falls within the critical value of D. Therefore, it can again be inferred that Lotka's law fits the author productivity distributionfor this data set. Details are given in Table 5.

Conclusion

In the present study, maximum number of authors have contributed one paper each. It was observed that with increase in number of contributions, there was a significant decrease in number of corresponding authors contributing to research papers. It was also found that expected number of authors shows a significant association with observed number of authors. The Lotka's Inverse Square law conforms to the study. Authorship pattern is now considered one of the main aspects of scientometric studies. It includes analysis of types of authors, their collaboration pattern, and number of authors, etc. Such studies will definitely be useful in understanding the development of a subject field.

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Table 4—Kolmogrov-Smirnov (K S) Test (when expected authors was calculated by using n=2.45)

Number of contributions (x)	Number of authors (y) [Observed]	Cumulative frequency of observed authors	Relative frequency of observed authors Fo	Number of authors (y) [Expected] by using n = 2.45	Cumulative frequency of expected authors Fe	Relative frequency of expected authors	Deviation D = Fe-Fo
1	4879	4879	0.7335	4879	4879	0.7379	0.0044
2	891	5770	0.8674	893	5772	0.8730	**0.0055**
3	365	6135	0.9223	331	6103	0.9230	0.0007
4	183	6318	0.9498	163	6266	0.9477	-0.0021
5	105	6423	0.9656	95	6361	0.9620	-0.0035
6	68	6491	0.9758	61	6422	0.9713	-0.0045
7	35	6526	0.9811	41	6463	0.9775	-0.0036
8	34	6560	0.9862	30	6493	0.9820	-0.0042
9	24	6584	0.9898	22	6515	0.9853	-0.0044
10	13	6597	0.9917	17	6532	0.9879	-0.0038
11	16	6613	0.9941	14	6546	0.9900	-0.0041
12	6	6619	0.9950	11	6557	0.9917	-0.0034
13	6	6625	0.9959	9	6566	0.9930	-0.0029
14	5	6630	0.9967	8	6574	0.9943	-0.0024
15	1	6631	0.9968	6	6580	0.9952	-0.0017
16	4	6635	0.9974	5	6585	0.9959	-0.0015
17	1	6636	0.9976	5	6590	0.9967	-0.0009
18	1	6637	0.9977	4	6594	0.9973	-0.0005
19	2	6639	0.9980	4	6598	0.9979	-0.0002
20	2	6641	0.9983	3	6601	0.9983	0.0000
21	1	6642	0.9985	3	6604	0.9988	0.0003
22	1	6643	0.9986	3	6607	0.9992	0.0006
23	3	6646	0.9991	2	6609	0.9995	0.0004
28	2	6648	0.9994	1	6610	0.9997	0.0003
30	1	6649	0.9995	1	6611	0.9998	0.0003
42	1	6650	0.9997	1	6612	1.0000	0.0003
44	1	6651	0.9998	0	6612	1.0000	0.0002
46	1	6652	1.0000	0	6612	1.0000	0.0000
	6652			6612			

Table 5—Kolmogrov-Smirnov (K S) Test (when expected authors was calculated by using n=2.46)

Number of contributions (x)	Number of authors (y) [Observed]	Cumulative frequency of observed authors	Relative frequency of observed authors Fo	Number of authors (y) [Expected] by using n = 2.46	Cumulative frequency of expected authors Fe	Relative frequency of expected authors	Deviation D = Fe-Fo
1	4879	4879	0.7335	4879	4879	0.7404	0.0069
2	891	5770	0.8674	887	5766	0.8750	**0.0076**
3	365	6135	0.9223	327	6093	0.9246	0.0023
4	183	6318	0.9498	161	6254	0.9490	-0.0008
5	105	6423	0.9656	93	6347	0.9631	-0.0024
6	68	6491	0.9758	59	6406	0.9721	-0.0037
7	35	6526	0.9811	41	6447	0.9783	-0.0028
8	34	6560	0.9862	29	6476	0.9827	-0.0035

Contd—

Table 5—Kolmogrov-Smirnov (K S) Test (when expected authors was calculated by using n=2.46)

—*Contd*

Number of contributions (x)	Number of authors (y) [Observed]	Cumulative frequency of observed authors	Relative frequency of observed authors Fo	Number of authors (y) [Expected] by using n = 2.46	Cumulative frequency of expected authors Fe	Relative frequency of expected authors	Deviation D = Fe-Fo
9	24	6584	0.9898	22	6498	0.9860	-0.0037
10	13	6597	0.9917	17	6515	0.9886	-0.0031
11	16	6613	0.9941	13	6528	0.9906	-0.0035
12	6	6619	0.9950	11	6539	0.9923	-0.0028
13	6	6625	0.9959	9	6548	0.9936	-0.0023
14	5	6630	0.9967	7	6555	0.9947	-0.0020
15	1	6631	0.9968	6	6561	0.9956	-0.0012
16	4	6635	0.9974	5	6566	0.9964	-0.0011
17	1	6636	0.9976	5	6571	0.9971	-0.0005
18	1	6637	0.9977	4	6575	0.9977	0.0000
19	2	6639	0.9980	3	6578	0.9982	0.0001
20	2	6641	0.9983	3	6581	0.9986	0.0003
21	1	6642	0.9985	3	6584	0.9991	0.0006
22	1	6643	0.9986	2	6586	0.9994	0.0007
23	3	6646	0.9991	2	6588	0.9997	0.0006
28	2	6648	0.9994	1	6589	0.9998	0.0004
30	1	6649	0.9995	1	6590	1.0000	0.0005
42	1	6650	0.9997	0	6590	1.0000	0.0003
44	1	6651	0.9998	0	6590	1.0000	0.0002
46	1	6652	1.0000	0	6590	1.0000	0.0000
	6652			6590			

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