Annals of Library and Information Studies
Vol. 64, December 2017, pp. 234-241

Author productivity and the application of Lotka's Law in LIS publications

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Received: 25 November 2016; revised: 06 December 2017; accepted: 25 December 2017

The paper examines authorship pattern of 556 papers published in *Journal of Documentation* during 2003 to 2015. In addition to the papers, a sample of 1550 references from a population of 15,529 unique references given at the end of the papers were selected using simple random sample method. It was found that almost half of the publications were written by single authors. Lotka's Law was tested on the resulting 2106 publications using Kolmogorov-Smrinov goodness-of-fit. The K-S test and the author productivity graph revealed that Lotka's law was applicable to the set LIS publications.

Keywords: Lotka's Law; Kolmogorov-Smirnov; Authorship pattern; Infometrics

Introduction

Journals are the principle means of communication of research results. As in other disciplines, LIS researchers and practitioners use journals to report research findings and exchange ideas among researchers of library and information science (LIS) professionals. Kohl and Davis[1] have suggested that the most preferred primary source of information for the LIS professionals is the library journal.

Infometrics is defined by Egghe[2] as "the science dealing with the quantitative aspects of information". This is a broad expression of a concept that also includes bibliometrics, the application of mathematical and statistical methods to books and other communication medium[3]. One area of bibliometric studies frequently used by library professionals is citation analysis, which is used for the purposes of acquisition, collection development and the tenures and promotions[4]. Citations analysis is an important area of research to explore the impact of geographic location and faculty status on the research productivity of librarians and faculty members[5].

There have been a number of studies conducted over the last many decades for assessing the publication trends of librarians. Results indicate that academic librarians publish more papers and books than non-academic librarians[6].

Existing studies on the publication productivity in LIS revealed that many of the samples differ significantly in size and breadth of source than those in Lotka's study. As a result of such observations concerning studies of Lotka's law in LIS and other fields, Pao[7] suggested that studies testing the appropriateness of Lotka's formula should be conducted in order to achieve valid results. There has yet to be a study that closely follows Lotka's methodology to test the inverse power law in the field of LIS. This study will investigate whether there is evidence of such applicability in this field.

Review of literature

Murphy[8] conducted a study of publications by 170 authors in the *Journal of American Chemical Society.* The study found that the number of actual contributions did not match up with the expected number of author contributions.

Schorr[9] tested the application of Lotka's law to publications in 618 contributions in two library science journals viz. *Library Quarterly* and *College & Research Libraries* for the period 1963-1972. The study found that Lotka's theory is not applicable to the field of library and information science.

Patra, Bhattachraya, and Verma[10] conducted a study of the literature on bibliometrics using data

from the *Library and Information Science Abstract* (LISA). The data used for the study included 3,781 records from 1969 to 2005. The Kolmogorov-Smirnov test showed that bibliometrics literature does not follow Lotka's law.

Patra and Chand[11] studied 3,396 records containing the term "India" from the online version of LISA. When testing Lotka's law they found that in Indian LIS literature 74% of the authors have one publication, about 12% have two publications and 4% have three publications. It was also found that the value of the exponent n to be -2.12 and the value of the constant, c is 0.64. The results of the K-S test indicated that Indian LIS literature follows Lotka's original distribution.

Askew[12] conducted a study to test Lotka's law of scientific publication productivity using the methodology outlined by Pao (1985)[13], in the field of library and information studies. A data set of 1,856 citations that were found using the ISI Web of Knowledge databases were studied. The values of n and c were calculated to be 2.1 and 0.6418 (64.18%) respectively. The results of the K-S goodness-of-fit test indicate that Lotka's law can be used as a valid means of predicting author productivity in the field of LIS.

The related literature reviewed above shows that Lotka's law of productivity has been tested extensively in the field of science. But there are limited studies that closely follow Lotka's methodology in the field of LIS. This study will investigate whether there is evidence of such applicability in this field.

Objectives of the study

- To examine the relative growth of contributions in the *Journal of Documentation*;
- To analyze the subject and geographical distribution of contributions;
- To analyze authorship pattern; and
- To examine the validity of Lotka's law in the field of Library and Information Studies.

Methodology

The data consisted of all the 556 articles published in the *Journal of Documentation* during 2003 to 2015 and a sample of 1550 unique references given at the end of these articles (10 percent of the population) selected at random. In the case of collaborative authors, only the name of the first author was counted. Co-authors and the articles authored by organizations were omitted since these would skew the data. All the references were saved in batches and exported into Excel for analysis. In this study the relative growth rate is calculated according to the equation suggested by Mahapatra[14]. The Collaborative coefficient (CC) has been measured by the method suggested by Ajiferuke[15]. The degree of collaboration is determined according to the formula given by Subramanyam (1983)[16]. In Lotka's Law, $\mathbf{x^n y = c,}$ the parameters *n* and *c* are calculated as per the steps followed by Pao(1985)[17]. Kolmogorov- Smrinov goodness-of-fit is used to compare the functions describing the observed and theoretical distributions of publications at 10 per cent level of significance as per the equation suggested by Black[18].

Analysis

Distribution of articles and references

Table 1 indicates that there are 556 articles and 20517 references in 13 volumes of the *Journal of Documentation* published during 2003-2015. Maximum number of references per article appeared in 2015 and minimum in 2004. The present study reveals that the average number of references per article has been increasing from 2003 to 2015. The average number of references per year is 1578.

Growth rate analysis

The growth rate analysis is done with respect to the relative growth rate and doubling time.

Relative growth rate per unit of publications per unit of time, ie, R(a) =

W1 = log w1 (Natural log of initial number of publications);

W2 = log w2 (Natural log of initial number of publications);

T2-T1=The unit difference between the initial time and final time.

Table 2 shows that the relative growth rate of articles is decreased from 0.79 in 2004 to 0.12 in 2015. The mean relative growth rate for the entire period is 0.23. The whole study period has witnessed a mean doubling time of 3.78. The analysis clearly

Table 1—Distribution of articles and references

Year	Vol. No.	No. of articles	No. of references	Average of references	Percentage of references
2003	59	28	979	35	4.77
2004	60	34	381	11	1.86
2005	61	44	1044	24	5.09
2006	62	36	1228	34	5.99
2007	63	41	1638	40	7.98
2008	64	43	1563	36	7.62
2009	65	42	1884	45	9.18
2010	66	42	1816	43	8.85
2011	67	43	1989	46	9.69
2012	68	43	1920	45	9.36
2013	69	43	1934	45	9.43
2014	70	54	2025	38	9.87
2015	71	63	2116	34	10.31
Total		556	20517	37	100.00

Table 2—Relative growth rate and doubling time for the *Journal of Documentation*

Year	No. of articles	Cumulative no. of articles	w1	w2	R(a)	Mean $R(a)=\frac{\sum R(a)}{n}$	Doubling time $Dt(a)=\frac{0.693}{R(a)}$	Mean $\frac{\sum Dt(a)}{n}$
2003	28	28	0	3.33	0.00			
2004	34	62	3.33	4.13	0.79		0.87	
2005	44	106	4.13	4.66	0.54		1.29	
2006	36	142	4.66	4.96	0.29		2.37	
2007	41	183	4.96	5.21	0.25		2.73	
2008	43	226	5.21	5.42	0.21		3.28	
2009	42	268	5.42	5.59	0.17	0.23	4.07	3.78
2010	42	310	5.59	5.74	0.15		4.76	
2011	43	353	5.74	5.87	0.13		5.34	
2012	43	396	5.87	5.98	0.11		6.03	
2013	43	439	5.98	6.08	0.10		6.72	
2014	54	493	6.08	6.20	0.12		5.97	
2015	63	556	6.20	6.32	0.12		5.76	
Total	556	100	6.32					

indicates that relative growth rate of articles has shown a declining trend, whereas a doubling time for publication has shown increasing.

Subject-wise distribution of articles

The subject wise distribution of papers in the *Journal of Documentation* is given in Table 3. The subjects are selected from the keywords given in each paper and are controlled with the help of Sears List of Subject Headings.

Table 3 shows that the top five dominating subjects in the articles are information retrieval with 95 (23.99%), information science with 47 (11.90%), digital libraries and internet with 34 (8.60%), cataloguing and classification with 32 (8.08%), user studies with 26 (6.57%) respectively. The analysis shows that the subjects dealt in the *Journal of Documentation* are a cross section of various subjects in the advanced field of Library and Information Studies.

Geographical distribution

Table 4 gives the geographical distribution of the articles under study. Out of 556 contributions, the highest number, i.e., 219 (39.4 per cent), has been contributed by United Kingdom followed by USA with 128 (23.0 per cent), Finland with 38 (6.8 per cent) and Canada with 36 (6.05 per cent). It is found

Table 3—Subject-wise distribution of papers

Sl. No.	Name	No. of papers	Percentage
1	Information Retrieval	133	24.0
2	Information science	66	11.9
3	Digital libraries, internet	48	8.6
4	Cataloguing, classification	45	8.1
5	Others	44	7.8
6	User Studies	37	6.6
7	Information Management	34	6.1
8	Information Literacy	27	4.8
9	Knowledge management	22	4.0
10	Public Libraries	21	3.8
11	Information system	20	3.5
12	Information seeking behavior	18	3.3
13	Information services + Reference services	13	2.3
14	Electronic Journals	11	2.0
15	Academic Libraries	10	1.8
16	Electronic Publishing	3	0.5
17	Special Libraries	3	0.5
18	Library Management	3	0.5
	Total	556	100.0

Table 4—Geographical distribution

Sl. No.	Name	Contribution	Percentage
1	UK	219	39.4
2	USA	128	23.0
3	Finland	38	6.8
4	Canada	36	6.5
5	Denmark	33	5.9
6	Australia	29	5.3
7	Sweden	28	5.0
8	Spain	21	3.7
9	Slovenia	16	2.8
10	Belgium	9	1.6
	Total	556	100.0

that there were only four contributions from Asian countries.

Authorship pattern and collaborative measures

The analysis shows that the maximum number of authors who contributed to the journal had a less tendency to work in collaboration. From Table 5 it is clear that the single authored articles were the maximum with 275 (49.46 per cent), followed by two authored articles with 181 (32.55 per cent). Also it is noted that no article has been contributed by more than five authors.

Collaborative measures

Collaborative measures such as number of authors, collaborative index, collaborative coefficient and degree of collaboration are given in Table 6.

The collaborative index shows a decreasing trend from 2010 onwards and the average for the study period is found to be 1.78, which shows a low level of collaboration. Also, the value of collaborative coefficient (CC) is 0.29, which is less than 0.50, and it shows lesser probability of multiple-authorship. The degree of collaboration (DC) has a decreasing trend

from 2003 to 2015 and the average value is found to be 0.51.

Author productivity and the application of Lotka's Law

Author productivity in the field of LIS shows that out of the 2106 unique authors, 1348 (64.01 per cent) produced one article, 342 (16.24 per cent) produced two articles and so forth. The number of authors who produced more than 16 articles is found to be quite small (only 0.14 per cent).

The first step in the testing of Lotka's law is to determine the value of ***n*** (Table 7).

$$n = \frac{17 * 13.75295 - 14.55107 * 21.32237}{17 * 13.75295 - 14.55107 * 14.55107}$$

n= -2.35371

Using the value of n, the value of c is estimated using the equation $c = \sum 1/x^n$

c=1/1.39084 = 0.718988

Table 5—Cumulative distribution of authorship patterns

Year	Single Author	Two Authors	Three Authors	Four Authors	Five Authors	Total
2003	13	7	8	0	0	28
2004	16	10	5	1	2	34
2005	26	10	5	2	1	44
2006	19	8	5	3	1	36
2007	14	17	5	3	2	41
2008	19	18	4	2	0	43
2009	26	7	6	2	1	42
2010	17	19	3	3	0	42
2011	20	16	2	4	1	43
2012	21	14	6	2	0	43
2013	26	13	2	1	1	43
2014	28	18	4	4	0	54
2015	30	24	6	3	0	63
Total	275	181	61	30	9	556
Percentage	49.46	32.55	10.97	5.40	1.62	100

Table 6—Collaborative measures

Year	No. of articles	Total number of authors	Collaborative Index(CI)	Collaborative Coefficient (CC)	Degree of Collaboration (DC)
2003	28	51	1.82	0.32	0.54
2004	34	65	1.91	0.31	0.53
2005	44	74	1.68	0.24	0.41
2006	36	67	1.86	0.29	0.47
2007	41	85	2.07	0.38	0.66
2008	43	75	1.74	0.31	0.56
2009	42	71	1.69	0.23	0.38
2010	42	76	1.81	0.33	0.6
2011	43	79	1.84	0.31	0.53
2012	43	75	1.74	0.29	0.51
2013	43	67	1.56	0.22	0.4
2014	54	92	1.70	0.27	0.48
2015	63	108	1.71	0.29	0.52
Total	556	985	1.78	0.29	0.51

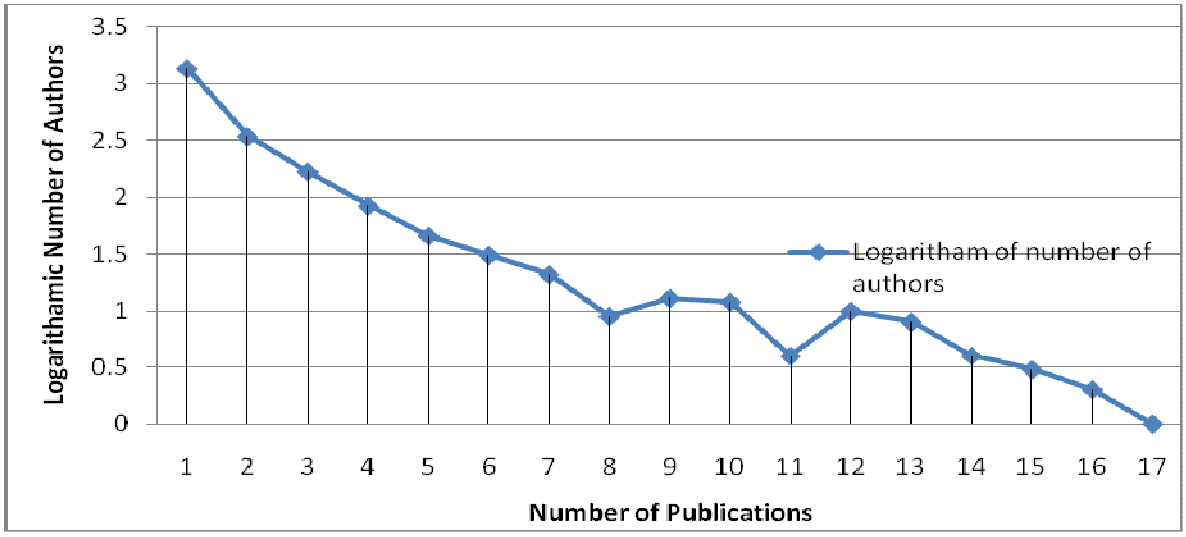

Fig. 1—Logarithmic number of authors producing n number of publications

Table 7—Computation of n

X	Y	X=log x	Y=log y	XY	XX
1	1348	0.00000	3.12969	0.00000	0.00000
2	342	0.30103	2.53403	0.76282	0.76282
3	168	0.47712	2.22531	1.06174	1.06174
4	84	0.60206	1.92428	1.15853	1.15853
5	46	0.69897	1.66276	1.16222	1.16222
6	31	0.77815	1.49136	1.16050	1.16050
7	21	0.84510	1.32222	1.11740	1.11740
8	9	0.90309	0.95424	0.86177	0.86177
9	13	0.95424	1.11394	1.06297	1.06297
10	12	1.00000	1.07918	1.07918	1.07918
11	4	1.04139	0.60206	0.62698	0.62698
12	10	1.07918	1.00000	1.07918	1.07918
13	8	1.11394	0.90309	1.00599	1.00599
14	4	1.14613	0.60206	0.69004	0.69004
15	3	1.17609	0.47712	0.56114	0.56114
16	2	1.20412	0.30103	0.36248	0.36248
17	1	1.23045	0.00000	0.00000	0.00000
	2106	14.55107	21.32237	13.75295	13.75295

The computed value of the constant c in the current data is c=0.718988 (71.89%), which indicates that the proportion of contributors who publish a single item in LIS is over 71 per cent. The calculated value of the constant c is just above the Lotka's value of c.

Table 8 shows that 64 per cent of the authors contributed only one article, 16 percent of the authors contributed two articles, and three articles by 8 per cent and so on. The expected value calculated is that 71 per cent of authors publish one article, two articles by 14 percent and three articles by 5 percent and so on. It reveals that there is not much difference between the predicted values and the observed values.

Kolmogorov-Smirnov (K-S) one sample goodness-of-fit test

The K-S goodness-of-fit test was conducted to determine whether Lotka's law predicts author publication productivity from the observed values. Looking at the difference column in Table 8, the maximum difference between the cumulative distributions, Dmax, is 0.00134.

Table 8—Observed and expected distribution of authors

x	y_x	Observed: % of authors ($y_x / \sum y_x$)	Observed: Cumulative % of authors	Expected: % of authors $C * 1/x^n$	Expected: Cumulative % of authors	Difference Col 4-Col.6
Col.1	*Col.2*	*Col.3*	*Col.4*	*Col.5*	*Col.6*	
1	1348	0.64007597	0.64008	0.71899	0.71899	-0.0789
2	342	0.16239316	0.80247	0.14066	0.85965	-0.0572
3	168	0.07977208	0.88224	0.05416	0.91382	-0.0316
4	84	0.03988604	0.92213	0.02752	0.94134	-0.0192
5	46	0.02184236	0.94397	0.01628	0.95761	-0.0136
6	31	0.01471985	0.95869	0.0106	0.96821	-0.0095
7	21	0.00997151	0.96866	0.00737	0.97558	-0.0069
8	9	0.0042735	0.97293	0.00538	0.98097	-0.008
9	13	0.00617284	0.97911	0.00408	0.98505	-0.0059
10	12	0.00569801	0.98481	0.00318	0.98823	-0.0034
11	4	0.00189934	0.9867	0.00254	0.99078	-0.0041
12	10	0.00474834	0.99145	0.00207	0.99285	-0.0014
13	8	0.00379867	0.99525	0.00172	0.99457	0.00069
14	4	0.00189934	0.99715	0.00144	0.99601	0.00114
15	3	0.0014245	0.99858	0.00123	0.99723	0.00134
16	2	0.00094967	0.99953	0.00105	0.99829	0.00124
17	1	0.00047483	1	0.00091	0.9992	0.0008
Total	2106					

The critical value is calculated by using the equation suggested by Black[18].

Critical value = $\frac{1.22}{\sqrt{n+1}} = \frac{1.22}{\sqrt{2.35371+1}} = \frac{1.22}{\sqrt{3.35371}} =$ 0.666188

The values of n and c were calculated to be 2.35771 and 0.718988 (71.90%) respectively. The Kolmogorov-Smirnov (K-S) one sample goodness-of-fit test was conducted at the 0.10 level of significance. The D_{max} value is 0.00134 and the resulting critical value is 0.666188. Since the critical value is greater than the Dmax (0.00134), we must fail to reject the null hypothesis that the distribution is not different from the distribution predicted by Lotka's law. Hence the Lotka's Law is applicable to Library and Information studies publications.

Conclusion

The study reveals that there was a declining relative growth rate of articles and an increasing number of citations per article in the *Journal of Documentation* over the years. Majority of the articles were single authored and most articles were contributed from UK and US. The method of least squares followed by Pao, author productivity graph and the K-S test showed that Lotka's Law is applicable in LIS publications. Hence it is concluded that Lotka's Law is essentially an inverse square power function that predicted the distribution of authors to publications in LIS.

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