

Lotka's Law and Author Productivity in the Economic Literature: A Citation Study

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Abstract - The present study is to analyze citation pattern of *Economica*, New Series as a source journal to determine the application of Lotka's law and author productivity in the economic literature. It is an international journal devoted to research in all branches of economics. The article covers 8347 citations appended to 302 articles appeared in volume 74, number 393 to volume 83, number 432 during the year 2007 to 2016. Findings indicate that 10 volumes (40 issues) of *Economica*, New Series contained 8347 citations in 302 articles which mean that average number of citations appeared 208.675 citations in each issue. Major forms of literature are journal articles 5328 (63.831%) and followed by books 2211 (26.489%) citations. Out of 5328 journal citations 1013 (19.013%) citations are single authored journals and 4315 (80.987%) citations are multi-authored journal. The Lotka's law is not suitable for the economic literature of author productivity distribution.

Keywords: Author Productivity, Citation Analysis, Economic Literature, *Economica*, New Series, Lotka's Law

I. INTRODUCTION

Citation analysis is a mathematical analysis of references or citations appended at the end of each scientific communication as an essential part of it. Analysis of cited papers is used as a measure of impact of individual articles, periodicals, authors, etc. and has become an accepted practice in almost all scientific communications and a well-established part of information research (Gawande & Choukhande, 2013). Citation analysis as a tool is used to identify the core references in a subject by counting the citations appended at the end of each scientific article. It is basically a technique, which involves the process of collection given in research writing and thereby helping in identification of significant sources of information. Citation analysis plays a promontory role for easy identification of earlier research (White, 1985).

Information professionals are conducting citation or bibliometric analysis in the specific areas of their institutions to know the utility of information resources available in their libraries. Citation analysis has also been used to find out the literature used by the scholars in different disciplines. This article tries to study the citation pattern of *ECONOMICA*, New Series journal to determine the application of lotka's law and author productivity in the economic literature.

II. LITERATURE REVIEW

A large number of citation analysis have been conducted on single journal in various subject fields in India and abroad such as Suryanarayana (2000) on Journal of Tobacco Research; Dutta and Sen (2001) on Indian Journal of Pure & Applied Mathematics; Das and Sen (2001) on Journal of Biosciences; Koley and Sen (2003) on Indian Journal of Physiology; Shokeen and Koushik (2003) on Indian Journal of Economics; Singh and Dominic (2006) on Allelopathy Journal; Biswas, Roy and Sen (2007) on Economic Botany; Kanungo (2007) on Journal of Asian Studies; Nattar (2009) on Indian Journal of Physics; Hadimani and Rajgoli (2010) on Applied Engineering in Agriculture; Wei (2018) on top five Economics Journals, Palanivel and Baskaran (2018) on Economic Affairs Journal and Chaudhari (2020) on Economic Theory Journal. However, there are no studies carried out so far on the International Journal 'Economica, New Series.'

Review of previous studies also based on author productivity and the application of Lotka's law in the field of various disciplines include Schorr (1974) found a law which was quadruple (x^{-4}), instead of the inverse quadratic Lotka (x^{-2}), in other experience about libraries organization. Voos (1974) studied the authors' productivity at the information science field, between 1966 and 1970, and compared the results with the Lotka's observation ($n=2$) and discovered that the distribution of authors adjusted itself so well to a new constant equal to $x^{-3.5}$. Vlachy (1978) presented a bibliography about Lotka and related work, among them about Bradford and Zipf, as well as distribution of frequencies and of bibliometrics.

Gupta (1987) analyzed and studied productivity models of authors and checked the applicability of Lotka's law to four different groups of data at a study about entomology of Nigeria. It is showed that Lotka's law, on its original shape, as inverse quadratic was not applicable to any of the four groups of data. Sen *et al.*, (1996) tried to estimate the Lotka's law at the domain of information science and checked that it is applicable to this field.

Sevukan and Sharma (2008) presented a detailed analysis of research performance of biotechnology faculties in Central Universities of India from 1997-2006. The results indicated that the growth of literature in biotechnology has steadily

increased from 15 articles in 1997 to 43 articles in 2006; two-authored publications predominate amongst the pattern of authorship; applicability of Lotka's law is validated from the values $n=2.12$, $C=0.669$, and $D=0.027$ obtained using least square method. Sobrino *et al.*, (2008) introduced an application of Lotka's law at whole of authors with publication in the field of information science between 1996 and 2007. The results showed the data: one pending equal a '2,75', the obtained it is lower in the work of Voos(1974), as in the Sen *et al.*,(1996), in this camp; a percentage of authors, executors of one work only, it is equal a 79 percent and a excellent adjust of the Lotka's law, to be application at the Kolmogorov-smirnov.

Kumar (2010) examined the applicability of Lotka's law as a general inverse power ($\alpha \neq 2$) and as an inverse square power relationship ($\alpha = 2$) to the distribution of the research productivity in CSIR, India. Two data sets of the research papers (6076 and 17681) contributed by CSIR's scientists during the period of 1988-1992 and 2004-2008 were collected from SCI CD-ROM and Web of science respectively. A K-S Test was applied to measure the degree of agreement between the distribution of the observed set of data against the inverse general power relationship and the theoretical value of $\alpha = 2$. It was found that the inverse square law of Lotka did not confirm as such.

Mishra *et al.*, (2010) showed log-log plot of number of authors and number of citations in figure and concluded the low and medium productive cited authors are not a good fit but the high productive authors can be said as a good fit the original Lotka's law. Sen (2010) demonstrated that how simply the value of c and a pertaining to the equation of lotka's law can be calculated. The value of an obtained according to the method described in the paper seems to be equally good, if not better than the value obtained through Pao's method. The method is much simpler compared to Pao's method. Tsai and Chiang (2011) performed K-S test to verify the reliability of Lotka's law. After checked by K-S test, the distribution of frequency indexes of author productivity is suitable for Lotka's law.

III. SCOPE OF THE STUDY

The present study covers 8347 citations appended to 302 articles appeared in volume 74 (2007) – volume 83 (2016) of the ECONOMICA, New Series. For this purpose, the journal 'Economica, New Series' has been selected as the source journal. It is quarterly publication which contains theoretical and empirical articles published from all parts of the International Research Community. It was first published in 1921 as Economica and from 1934 it was renamed as Economica, New Series.

IV. OBJECTIVES OF THE STUDY

The objectives of the current study are

1. To identify the year-wise distribution of articles.
2. To determine the frequency distribution of reference cited.

3. To classify the form-wise distribution of cited literature.
4. To examine the nature of authorship pattern.
5. To identify the authorship pattern of journal articles.
6. To ascertain the author productivity of journal articles.
7. To find out as to what extent, the author productivity of cited journal articles conforms to the Lotka's law.

V. SOURCE JOURNAL: ECONOMICA

Economica, New series is an international journal devoted to research in all branches of economics. Theoretical and empirical articles are published from all parts of the international research community. Economica, New Series is a leading economics journal, appearing high in the published citation rankings. In addition to the main papers which make up each issue, there is an extensive review section, covering a wide range of recently published title at all levels. From time-to-time special issues on selected topics are published, and are available as either single back issue or, if possible, in the current year, are included in the annual subscription. Economica (ISSN 0013-0427) is published quarterly by Blackwell Publishers Ltd., 108 Cowly Road, Oxford OX4 1JF, UK, on behalf of The London School of Economics and Political Science and The Suntory and Toyota International Centres for Economics and Related Disciplines, and printed by J. W. Arrowsmith Ltd., Bristol.

VI. MATERIALS AND METHODS

For this present study the volumes 74 (2007) – 83 (2016) was taken into consideration. Data were collected with adequate details as such title of the articles, name of the contributors, their address and number of pages written for each article published between the years 2007 – 2016. After that, each individual article is scanned, checked, examined, and tabulated for necessary data into separate sheets. At the same time, the references appended by the respective authors at the end of each article were also scanned, counted, and tabulated. Finally, all the collected data were recounted, compiled, tabulated and analyzed for making observations.

VII. LOTKA'S LAW

It was proposed an inverse square law relating to scientific papers to the number of contributions made by each author. Lotka's law(1926) describes the frequency of publication by authors in each field. It states that the number of authors making n contributions is about $1/n^a$ of those making one contribution; and the proportion of all contributors, that make a single contribution, is about 60 percent. This means that out of all the authors in each field, 60 percent will have just one publication, and 15 percent will have two publications ($1/2^2$ times \times 60), 7 percent of authors will have three publications ($1/3^2$ times \times 60), and so on. This law can be expressed as

$$X^n \times y = c, \quad \text{or} \quad y = c/x^n, \quad \text{or} \quad y = c \times x^n \dots\dots\dots(1)$$

Where, x is the number of publications of interest (1,2, etc); n is an exponent that is constant for a given set of data; y is the expected percentage of authors with frequency x of publications, and c is a constant.

This study followed the recommendation conducted analysis which calculated the slope n value and the constant c value by using the Kolmogorov-Smirnov (K-S) examination to confirm whether the horticulture literatures consistent with the Lotka's law or not. It can be expressed as Pao (1986).

$$n = (N\sum XY - \sum X \sum Y) / (N\sum X^2 - (\sum X)^2) \dots\dots\dots(2)$$

where, N is the number of data pairs considered; X is the logarithm of x (x is the number of articles) and Y is the logarithm of y (y is the number of authors). Then get the constant c value by following equation:

$$c = 1/ \sum_{i=1}^{p-1} 1/X^n + 1/(n-1) (p^{n-1}) + 1/2p^n + \dots\dots\dots + n/24(p-1)^{n-1} \text{ or, } c = 1/ \sum (1/x^n) \dots\dots\dots(3)$$

To verify that the observed distribution of author productivity fits the estimated distribution, he suggested applying the non-parametric Kolmogorov-Smirnov (K-S)

goodness-of-fit test. To this end, the maximum difference between the real and estimated accumulated frequencies was calculated, and this value was then compared with the critical value (c.v.) obtained from the following equation:

$$c.v. = 1.63/ \{ \sum y_x + (\sum y_x/10) \}^{1/2} \dots\dots\dots(4)$$

D = Dmax = Differences between the columns of the observed and expected cumulative frequencies
 = $\sum f(x) - \sum (y_x/\sum y_x)$

VIII. DATA ANALYSIS AND DISCUSSION

There is total 8347 citations appended to 302 articles contributed by 549 authors during the year 2007 – 2016. Citations are found at the end of each article under the heading “References”.

A. Volume-Wise Distribution of Articles and Citations

Table I and Fig. 1 show the year and volume-wise distribution of articles and citations during the year 2007 - 2016. It shows the trend regarding the productivity of the articles during the given period.

TABLE I VOLUME-WISE DISTRIBUTION OF ARTICLES AND CITATIONS

Year	Volume (No.)	Total articles	No. of citations	Average no. of citations per article	% of 3	% of 4
2007	74 (393-396)	28	823	29.393	9.272	9.860
2008	75 (397-400)	32	885	27.656	10.596	10.603
2009	76 (401-404)	34	893	26.265	11.257	10.698
2010	77 (405-408)	30	775	25.833	9.934	9.285
2011	78 (409-412)	31	839	27.064	10.265	10.052
2012	79 (413-416)	28	752	26.857	9.272	9.009
2013	80 (417-420)	29	752	25.931	9.602	9.009
2014	81 (421-424)	32	920	28.75	10.596	11.022
2015	82 (425-428)	30	952	31.733	9.934	11.405
2016	83 (429-432)	28	756	27.000	9.272	9.057
Total	10 Volumes	302	8347	27.639	100.000	100.000

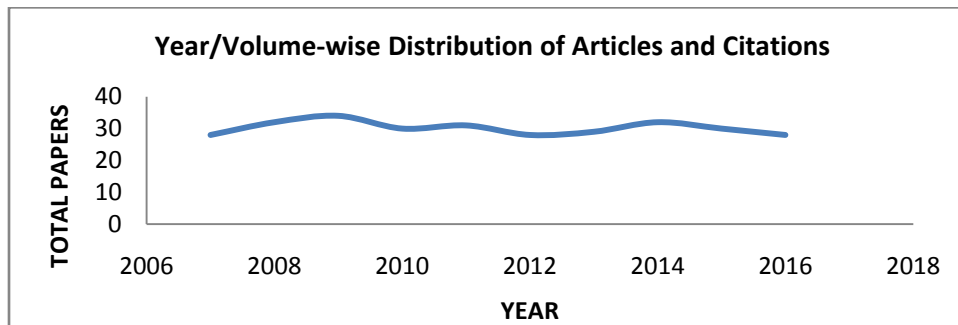


Fig. 1 Year/Volume-wise Distribution of Articles and Citations

10 volumes (40 issues) of *Economica*, New Series contained 8347 citations in 302 articles which mean that every issue published 7.55(302 articles/40 issues) articles on an average having 27.639 citations in each article during this study period. Average number of citations appeared 208.675

(8347 citations/40 issue) citations in each issue. The highest number of articles published during 2009 is 34 (11.257%). The year 2015 has the highest number of citations i.e., 952 (11.405%).

B. Frequency Distribution of Cited References

Table II shows the frequency distribution of cited references during the study period 2007-2016.

TABLE II FREQUENCY DISTRIBUTION OF CITED REFERENCES

No. of Citations Per Issue	No. of Issues (f) v. 74(393) – v. 83(332)	%	Mid-value (x) of first column	f x
50 – 74	2	5.00	62	124
75 – 99	8	20.00	87	696
100 – 124	3	7.50	112	336
125 – 149	14	35.00	137	1918
150 – 174	7	17.50	162	1134
175 – 199	6	15.00	187	1122
Total	N =40	100.00		Σfx =5330

Therefore, the average number of citations appeared per issue= $\Sigma fx/N = 5330/40 = 133.25 = 133$ (approx.). Table II shows average 133 citations are appeared to each issue. 125-149 (35.00%) is the highest range of citations per issue and 50-74 (5.00%) is the lowest range of citations per issue.

C. Form - Wise Distribution of Cited Literature

Table III and Fig. 2 shows the distribution of citations among different documentary forms such as Journals, Books, Working Papers, Discussion Papers, etc.

TABLE III FORM-WISE DISTRIBUTION OF CITED LITERATURE

Form of Literature	Total No. of Citation	Cumulative Citation	Percentage	Cumulative Percentage
Journals	5328	5328	63.831	63.831
Books	2211	7359	26.489	90.320
Working Papers	405	7944	4.852	95.172
Discuss Papers	163	8107	1.953	97.125
Websites	47	8154	0.563	97.688
Theses	44	8198	0.527	98.215
Reports	38	8236	0.455	98.670
Conference Proceedings	37	8273	0.443	99.113
Un-publish Documents	27	8300	0.324	99.437
Research Papers	16	8316	0.122	99.629
Government Publication	14	8330	0.167	99.796
Monographs	10	8340	0.120	99.916
Others	7	8347	0.084	100.000
Total	8347	8347	100.000	100.000

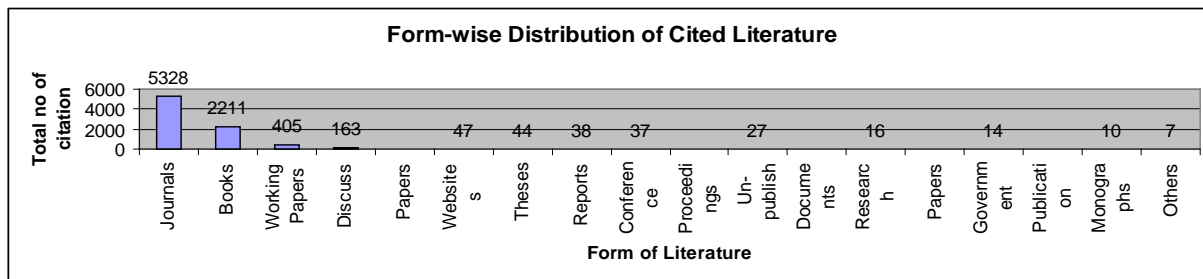


Fig. 2 Form-wise Distribution of Cited Literature

It may be observed from the Table III that 5328 (63.831%) citations are of Journals followed by Books 2211(26.489%). In other words, Journals and Books constitute 7359 (90.320%). Next to the Journals and Book are working papers 405(4.852%). Remaining 4.828% of citations are discussion papers, www, theses, reports etc.

D. Authorship Pattern of Journal Articles

Table IV displays on the authorship pattern of journal articles in 5328 citations during study period.

TABLE IV AUTHORSHIP PATTERN OF JOURNAL ARTICLES

Authorship Patterns	No of Citations	Cumulative Citations	Percentage of Citations	Cumulative Percentage
Single	1013	1013	19.013	19.013
Two	2075	3088	38.945	57.958
Three	1269	4357	23.818	81.776
Four	656	5013	12.312	94.088
Five	173	5186	3.246	97.334
Six	49	5235	0.920	98.254
Seven	37	5272	0.694	98.948
Eight	25	5297	0.470	99.418
Nine & above	22	5319	0.413	99.831
Anonymous	9	5328	0.169	100.000
Total	5328	5328	100.000	100.000

Table IV indicates that out of 5328 citations, the maximum articles written by single authors 1013 (19.013%) and two authors 2075 (38.945%). It is followed by three authors 1269 (23.818%) and four author 656 (12.312%). Remaining of the citations is contributed by more than five and above authors.

E. Authorship Patterns of Articles

Table V gives the distribution of the cited articles with respect to the number of authors. Out of 5328 references cited 1013 (19.013%) are single authored journals.

TABLE V YEAR WISE DISTRIBUTION OF ARTICLES

No. of Authors Year	1	2	3	4	5	6	7	8	9 &<	An.	No. of Articles
1997	95	177	94	38	13	3	2	1	2	8	433
1998	33	116	42	15	3	-	-	-	-	-	209
1999	40	54	73	18	4	-	1	-	1	-	191
2000	17	44	25	11	1	1	-	-	-	-	99
2001	38	53	30	9	2	-	-	-	-	-	132
2002	12	32	12	2	-	-	-	-	-	-	58
2003	41	51	49	21	10	3	1	-	-	-	176
2004	18	28	4	2	4	-	-	-	-	-	56
2005	13	62	42	11	5	1	-	1	-	-	117
2006	82	174	90	59	9	4	2	4	1	-	425
2007	66	96	68	43	13	2	-	-	1	-	338
2008	88	167	83	60	11	7	-	2	1	-	419
2009	25	56	42	14	7	-	2	1	2	-	149
2010	24	54	27	26	4	3	-	1	-	-	139
2011	115	248	139	68	28	4	3	7	5	1	618
2012	61	171	119	64	16	2	4	1	1	-	439
2013	90	126	105	56	10	3	3	1	3	-	397
2014	75	134	65	30	13	6	5	4	3	-	335
2015	59	130	74	45	10	5	7	1	1	-	332
2016	21	102	55	64	10	5	7	1	1	-	266
Total	1013	2075	1269	656	173	49	37	25	22	9	5328
Percentage (%)	19.013	38.945	23.818	12.312	3.246	0.920	0.694	0.470	0.413	0.168	100.000

An. = Anonymous, D= Dissertations

4315(80.987%) are multi-authored journals. Citations to single author contributions are more in number in the year 2011 with 115 citations followed by 95 citations in 1997 and 90 citations in 2013. The lowest citations to single author publications are 12 in 2002. Among the multi-author articles, the share of two author contributions is found to be more i.e., 2075 citations (38.945%), followed by 1269 citations (23.818%) of three author contributions and 656 citations (12.312%) of four author contributions. The study

reveals that team research is on the increase in the field of Economic Literature.

E. Author Productivity

The study has analyzed the citations by number of authors to assess the pattern of authorship in the economic literature. Two authors (38.945%) are the highest in the cited journals followed by three authors (23.818%), and single author (19.013%).

TABLE VI DISTRIBUTION OF AUTHOR PRODUCTIVITY

No. of Publication (x)	No. of Authors (y)	% y	Xy	Σxy	% of Σxy	Σy	% of Σy
15	1	0.019	15	15	0.111	1	0.019
14	3	0.056	42	57	0.424	4	0.075
13	1	0.019	13	70	0.520	5	0.094
12	4	0.075	48	118	0.877	9	0.169
11	2	0.038	22	140	1.040	11	0.207
10	10	0.188	100	240	1.783	21	0.395
9	1	0.019	9	249	1.850	22	0.414
8	25	0.470	200	449	3.336	47	0.884
7	37	0.696	259	708	5.260	84	1.580
6	49	0.921	294	1002	7.444	133	2.500
5	173	3.252	865	1867	13.870	306	5.753
4	656	12.333	2624	4491	33.363	962	18.086
3	1269	23.858	3807	8298	61.645	2231	41.943
2	2075	39.011	4150	12448	92.475	4306	80.955
1	1013	19.045	1013	13461	100.000	5319	100.000
Total	5319	100.000	13461	13461	100.000	5319	100.000

From Table VI it is also observed that would be a total of 13461 articles with 5319 (5328-9 anonymous authors) authors with an average of 2.526 authors for each article.

The result indicates that the literatures of data were usually generated by multi-authors.

TABLE VII CALCULATION FOR THE EXPONENT 'N'

No. of Publication(x)	No. of Authors(y)	X= Log x	Y= Log y	XY	X ²
15	1	1.176	0.000	0.000	1.383
14	3	1.146	0.477	0.547	1.314
13	1	1.114	0.000	0.000	1.241
12	4	1.079	0.602	0.650	1.165
11	2	1.041	0.301	0.313	1.084
10	10	1.000	1.000	1.000	1.000
9	1	0.954	0.000	0.000	0.911
8	25	0.903	1.398	1.262	0.816
7	37	0.845	1.568	1.325	0.714
6	49	0.778	2.033	1.602	0.606
5	173	0.669	2.436	1.703	0.489
4	656	0.602	2.980	1.793	0.362
3	1269	0.477	3.326	1.586	0.228
2	2075	0.301	3.125	1.052	0.091
1	1013	0.000	3.246	0.000	0.000
Total	5319	12.115	22.492	12.833	11.404

F. Calculation of the Exponent 'n' for Economics Literature

Table VII shows the detail account for the calculation of the exponent 'n' for Economics literature during study period.

By the result of calculation on Table VII, it could bring into the equation of the Lotka's law as below to calculate n value
 $n = (N\sum XY - \sum X \sum Y) / \{N\sum X^2 - (\sum X)^2\}$

$$= (15 \times 12.157 - 12.114 \times 21.525) / \{15 \times 11.401 - (12.114)^2\}$$

$$= (182.355 - 260.753) / (171.015 - 146.749)$$

$$= -78.398 / 24.401 = -3.213$$

G. Application of Lotka's Law

Table VIII shows the calculation for measuring the application of Lotka's Law in Economics literature.

TABLE VIII THE K-S TEST FOR ECONOMICS LITERATURE

No. of Publications(x)	No. of Authors(y)	$y_x / \sum y_x$	$\sum (y_x / \sum y_x)$ (Observed)	$1/x^n$	$F_x = C(1/x^n)$	$\sum f_x$ (Expected)	D=
1	1013	0.190	0.190	1.000	0.896	0.896	0.687*
2	2075	0.390	0.580	0.085	0.076	0.972	0.392
3	1269	0.239	0.819	0.020	0.018	0.990	0.159
4	656	0.123	0.942	0.007	0.006	0.996	0.051
5	173	0.032	0.974	0.003	0.002	0.998	0.021
6	49	0.009	0.983	0.001	0.001	0.999	0.009
7	37	0.007	0.990	-	-	-	-
8	25	0.005	0.995	-	-	-	-
9	1	0.000	0.995	-	-	-	-
10	10	0.002	0.997	-	-	-	-
11	2	0.001	0.998	-	-	-	-
12	4	0.001	0.999	-	-	-	-
13	1	0.000	0.999	-	-	-	-
14	3	0.001	1.000	-	-	-	-
15	1	0.000	1.000	-	-	-	-
Total	5319	1.000	1.000	1.116	-	-	-

Value c is calculated by using following formula

$$c = 1 / \sum_{i=1}^{p-1} 1/X^n + 1/(n-1) (p^{n-1}) + 1/2p^n + \dots + n/24$$

$$\text{or } c = 1 / \sum (1/x^n) = 1/1.116 = 0.896$$

when we get n = -3.213 and c = 0.896, it explored:

$$f(x) = c (1/x^n) = 0.896 (1/x^{-3.213}) = 0.896 \times x^{3.213}$$

From Table VIII, we can find

$$D (D = \max | \sum f(x) - \sum (y_x / \sum y_x) | = 0.687$$

According to K-S test, the critical value (c.v.) is

$$c.v. = 1.63 / \sqrt{\{\sum y_x + \sqrt{(\sum y_x / 10)}\}} = 0.0178$$

Here, Dmax is greater than the K-S test critical value. Therefore, this result indicated that the distribution of author productivity is not match by the Lotka's law. The consequence means the Lotka's law is not suitable for the literature of author productivity distribution in economics research.

IX. FINDINGS OF THE STUDY

Based on the analysis carried out on the 302 articles with total of 8347 citations contributed by 549 authors, the following conclusions are drawn.

1. Economica, New Series were published an average of 30 articles per volume.
2. Average 133 citations were appended to each issue and average 28 citations were appended to each article.
3. Most of the citations 5328 (63.831%) were drawn from the journals. A sizable number of citations 2211 (26.489%) were from books. In other words, Journals and Books constitute 7359 (90.320%).
4. The maximum articles were written by single author 1013 (19.013%) and two authors 2075 (39.011%). Multi-authored journals are 4315 (80.987%). Citations.
5. The distribution of author productivity is not match by the Lotka's law. The consequence means the Lotka's law is not suitable for the economic literature of author productivity distribution.

X. CONCLUSION

Information professionals are conducting citation or bibliometric analysis in the specific areas of their institutions to know the utility of information resources available in their libraries. Citation analysis has also been used to find out the literature used by the scholars in different disciplines. This article tries to study the citation pattern of ECONOMICA, New Series journal to determine the application of Lotka's Law and author productivity in

the economic literature. Generally, Lotka's Law describes the frequency of publications by authors in each subject/discipline. In this article, an attempt has been made to study the applicability of the Lotka's Law to the publication of a journal named ECONOMICA, New Series covered Economic subject or discipline. A K-S test is applied for the fitness of Lotka's Law does not fit to the Economics data. Thus, distribution frequency of the authorship doesn't follow the exact Lotka's Inverse Law.

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