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APPLICATION OF LOTKA'S LAW IN BIOLOGY LITERATURE OF CENTRAL UNIVERSITIES IN INDIA

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INTRODUCTION

The productivity of scientific researchers which is normally referred to as scientific productivity is measured in terms of their scientific output which are published through different forms viz. papers, reports, books and technical output. These measures of scientific productivity have been generally accepted and used since the beginning of the twentieth century. It examines the prevailing trend in carrying out the research process in science in terms of the extent to which the research performance is concentrated by single authors. Lotka's law is a classical method used to test the regularity in the publication activity of authors of scientific literature. It describes the frequency of publication by authors in a given field. In view of the above, it was intended to study growth of biology literature in central universities of India and test Lotka's law using Inverse Power Law model.

OBJECTIVES OF THE STUDY

- To study the growth of publications of central universities in the field of biology; and
- To test the fitness of Lotka's law on the biology literature of central universities in India.

DEFINITION OF LOTKA'S LAW

The statistical analysis of scientific literature began almost 50 years before the term 'bibliometrics' was coined. In 1926, Alfred J. Lotka published his pioneering study on the frequency distribution of scientific productivity determined from a decennial index (1907-1916) of Chemical Abstracts. It states that 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 in the region of 60 percent. This means that out of all the authors in a given field, 60 percent will have just one publication; 15 percent will have two publications ($1/2^2$ times 60); 7 percent will have three publications ($1/3^2$ times 60), and so on[1-4].

METHODS AND TECHNIQUES

The data used for the present study were obtained from the ISI Web of Science – Science Citation Index Expanded (SCIE). The Web of Science is an online edition that combines the three databases SCI expanded (an SCI edition with broader coverage), the SSCI and the A&HCI in a unique on-line database published from Institute of Scientific Information (ISI), Philadelphia. The whole data of the present study based on SCIE for nineteen central universities in India for a period of 14 years spanning between 1999 and 2012. A total of 8820 records of various types comprising Articles, Meeting Abstracts, Reviews, Bibliographic Items, Editorial Material, Letters, Corrections, and News Items were retrieved during June 2012 and January 2013.

TESTING OF LOTKA'S LAW

For the present study, Lotka's Inverse Power Law model that states the function describing the pattern of productivity of authors publishing in a specified subject field in a fixed time period is mathematically represented as:

$$g(x) = kx^{-n} \qquad \text{(eq. 1)}$$

Where *k* and *n* are parameters to be estimated from the data

The exponent *n* is often fixed at 2, in which case the law is known as the *inverse square law of scientific productivity.* However, given that the exponent *n* predicts the relative number of authors at each productivity level it would seem useful to calculate it. In the present study, *Maximum Likelihood Method* has been used. It can be mathematically expressed as:

$$n = \frac{\sum \times In\, g(x)}{\sum \times g(x)} = -\frac{\xi(n)}{\xi(n)} \qquad \text{(eq. 2)}$$

$X = 1, 2, 3, \ldots\ldots\ldots\ldots\ldots\ldots x_{max}$

Where $\xi(.)$ denotes the Riemann Zeta Function

The mathematical formula for calculating the parameter *k* of the Lotka's model equation is:

$$k = \frac{1}{\sum_{X=1}^{P-1} 1/x^n + 1(n-1)(P^{n-1}) + 1/2P^n + n/24*(P-1)^{n+1}}$$

(eq. 3)

In order to verify that the observed distribution of author productivity fits the estimated distribution, goodness-of-fit test using chi-square has been used with the following equation:

$$\chi 2 = \frac{[\sum (f_o - f_e)^2]}{f_e} \qquad \text{(eq. 4)}$$

Where, f_o is the observed number of authors with x Publications

f_e is the expected value, $g(x) = kx^{-n}$

RESULTS AND DISCUSSION

Annual research publications

University-wise total research productivity of biology scientists in central universities of India for 1999 – 2012 based on SCIE has been presented in Table 1. From the results, it was noted that University of Delhi ranks first in order by contributing 22.49 percent of total research output. The second place in order is recorded by Banaras Hindu University which shares 20.45 percent. Jawaharlal Nehru University contributing 12.69 percent to the total research output of the central universities takes third place in order. There is a wide gap between the research contribution of Delhi University and Jawaharlal Nehru University. The contribution of Delhi University is almost double that of Jawaharlal Nehru University. Aligarh Muslim University stands at fourth place in order contributing 12.35 percent followed by University of Hyderabad (9.41%). The four universities namely University of Allahabad, Jamia Millia Islamia, Pondicherry University, North-Eastern Hill University, and Visva Bharati Santiniketan yield the percentage share between 2 and 4 percent of total research output respectively. while the other universities Assam University, Central Agricultural University, Manipur University, University of Mizoram, Tripura University, Babasaheb Bhimrao Ambedkar University, Nagaland University, and Rajiv Gandhi University share less than 1 percent which was found to be quite low.

Author Productivity

The author productivity is determined in the present study on the basis of number of papers contributed by the biology researchers in central universities of India. A total of 11418 authors contributed 8820 papers to biology literature were analysed. Table 2 shows the distribution of the number of articles published by each author. The study revealed that around 59.49 percent of the authors contributed only one paper in the field of biology. Hence it ranks first in order with respect to the total number of contribution

during the period of study. The authors who contributed two papers were 15.73 percent and it is placed next in the order.

The contributors of three papers recorded 6.93 percent and it is ranked third place in order. The results of analysis brought out a fact that when the number of contributions increases, the number of authors decreases. In the light of the above, a greater level of research performance was noted among a few biology researchers in central universities of India. It is noteworthy that the contribution from one paper to nine papers constitutes 94.35 percent of the total output. Further, it portraits the range of authors who have contributed more than 10 papers to the greatest output of the study constitutes the remaining less percent of 5.65.

Table 1: Distribution of Total Research Output of Central Universities

Sl. No.	Name of the University	No. of Publications	%	Cum %
1	University of Delhi (Delhi)	1984	22.49	22.49
2	Banaras Hindu University (Varanasi, Uttar Pradesh)	1804	20.45	42.94
3	Jawaharlal Nehru University (New Delhi)	1119	12.69	55.63
4	Aligarh Muslim University (Aligarh, Uttar Pradesh)	1089	12.35	67.98
5	University of Hyderabad (Andhra Pradesh)	830	9.41	77.39
6	University of Allahabad (Uttar Pradesh)	343	3.89	81.28
7	Jamia Millia Islamia (New Delhi)	311	3.53	84.80
8	Pondicherry University (Pondicherry)	289	3.28	88.08
9	North-Eastern Hill University (Arunachal Pradesh)	287	3.25	91.33
10	Visva Bharati Santiniketan (West Bengal)	218	2.47	93.81
11	Tezpur University (Assam)	110	1.25	95.05
12	Assam University (Assam)	85	0.96	96.02
13	Central Agricultural University (Manipur)	84	0.95	96.97
14	Manipur University (Manipur)	63	0.71	97.68
15	University of Mizoram (Aizwal, Mizoram)	61	0.69	98.37
16	Tripura University (Tripura)	45	0.51	98.88
17	Babasaheb Bhimrao Ambedkar University (Lucknow)	42	0.48	99.36
18	Nagaland University (Nagaland)	29	0.33	99.69
19	Rajiv Gandhi University (Arunachal Pradesh)	27	0.31	100.00
Total		8820	100.00	

It could be deduced from the discussion that when the number of published papers increases, the number of contributing authors decreases. More number of publications by a researcher in any field requires high degree of inquisitiveness, competencies, efficiency, presences and exposure to literatures. That is the reason, in the present study, only a few authors have contributed more number of papers. Moreover author productivity is

influenced by the nature of university in which the researchers are attached to, area of specialization and availability of infrastructure.

Fitting of Lotka's Law

As stated in the objectives of the study, it is appropriate to examine and analyse the implications of Lotka's law in relation to author productivity on biology research publications made by biology researchers in central universities of India. Lotka's law is a classical method used to test the regularity in the publication activity of authors of scientific literature. To validate Lotka's law, the inverse square law of scientific productivity using maximum Likelihood Method was adopted. In order to verify that the observed distribution of author productivity fits the estimated distribution, goodness-of-fit

Table 2: Distribution of Author productivity

No. of Contribution	No. of Authors	Percentage	Cumulative Percentage
1	6793	59.49	59.49
2	1796	15.73	75.22
3	791	6.93	82.15
4	492	4.31	86.46
5	298	2.61	89.07
6	228	2.00	91.07
7	157	1.38	92.45
8	124	1.09	93.54
9	92	0.81	94.35
10	64	0.56	94.91
11	58	0.51	95.42
12	47	0.41	95.83
13	55	0.48	96.31
14	53	0.46	96.77
15	34	0.3	97.07
16	32	0.28	97.35
17	28	0.25	97.6
18	21	0.18	97.78
19	14	0.12	97.9
20	13	0.11	98.01
21	15	0.13	98.14
22	22	0.19	98.33
23	10	0.09	98.42
24	7	0.06	98.48
25	13	0.11	98.59
26	14	0.12	98.71
27	7	0.06	98.77
28	9	0.08	98.85
29	3	0.03	98.88
>30	128	1.12	100
Total	11418	100	

test using chi-square was used. Thus, a calculation was done using the equations (1 – 4) to identify the values of n and k to test whether application of Lotka's law fits to the research productivity of biology literature in central universities of India. From the calculation, based on the data presented in Table 3, it was found that the calculated values of Maximum Likelihood Estimator, n and k are 0.24, 2.66 and 0.78 respectively. The C.V. at 0.05 significant level for 29 degrees of freedom is 42.56 and the calculated value of Chi-Square (X^2) obtained in this case is 5309.368. On comparing, it was found that the calculated value of Chi-Square is greater than the critical value. Therefore, it can be concluded that the Lotka's law does not fit in the observed given author productivity distribution of biology literature of central universities in India.

Table 3: Fitting of Lotka's Law

X	g(x)	X=log x	X *g(x)	x^{-n}	Fraction of Expected No. of authors	f_o	f_e	f_o-f_e	$(f_o-f_e)^2$	CHI = $(f_o-f_e)^2/ f_e$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	6793	0	0	1	0.78	6793	8890.9	2097.9	4401184.4	495.0
2	1796	0.301	540.6499	6.32033	0.123411	1796	1406.6	389.4	151632.4	107.8
3	791	0.477121	377.4029	18.58414	0.041971	791	477.6	313.4	98219.6	205.7
4	492	0.60206	296.2135	39.94658	0.019526	492	222.3	269.7	72738.1	327.2
5	298	0.69897	208.2931	72.3203	0.010785	298	122.0	176.0	30976.0	254.0
6	228	0.778151	177.4185	117.4579	0.006641	228	75.2	152.8	23347.8	310.3
7	157	0.845098	132.6804	176.9949	0.004407	157	50.2	106.8	11406.2	227.4
8	124	0.90309	111.9832	252.4756	0.003089	124	34.2	89.8	8064.0	235.8
9	92	0.954243	87.79031	345.3704	0.002258	92	25.1	66.9	4475.6	178.5
10	64	1	64	457.0882	0.001706	64	19.4	44.6	1989.2	102.7
11	58	1.041393	60.40078	588.9854	0.001324	58	14.8	43.2	1866.2	125.9
12	47	1.079181	50.72152	742.3729	0.001051	47	11.4	35.6	1267.4	111.2
13	55	1.113943	61.26688	918.5215	0.000849	55	9.1	45.9	2106.8	231.0

X	g(x)	X=log x	X *g(x)	x^{-n}	Fraction of Expected No. of authors	f_o	f_e	f_o-f_e	$(f_o-f_e)^2$	CHI = $(f_o-f_e)^2/ f_e$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
14	53	1.146128	60.74479	1118.666	0.000697	53	6.8	46.2	2134.4	312.1
15	34	1.176091	39.9871	1344.011	0.00058	34	5.7	28.3	800.9	140.5
16	32	1.20412	38.53184	1595.729	0.000489	32	4.6	27.4	750.8	164.7
17	28	1.230449	34.45257	1874.969	0.000416	28	4.6	23.4	547.6	120.1
18	21	1.255273	26.36072	2182.855	0.000357	21	3.4	17.6	309.8	90.6
19	14	1.278754	17.90255	2520.488	0.000309	14	3.4	10.6	112.4	32.9
20	13	1.30103	16.91339	2888.948	0.00027	13	2.3	10.7	114.5	50.2
21	15	1.322219	19.83329	3289.299	0.000237	15	2.3	12.7	161.3	70.7
22	22	1.342423	29.5333	3722.582	0.00021	22	2.3	19.7	388.1	170.2
23	10	1.361728	13.61728	4189.827	0.000186	10	1.1	8.9	79.2	69.5
24	7	1.380211	9.661479	4692.042	0.000166	7	1.1	5.9	34.8	30.5
25	13	1.39794	18.17322	5230.226	0.000149	13	1.1	11.9	141.6	124.2
26	14	1.414973	19.80963	5805.359	0.000134	14	1.1	12.9	166.4	146.0
27	7	1.431364	10.01955	6418.412	0.000122	7	1.1	5.9	34.8	30.5

X	g(x)	X=log x	X *g(x)	x^{-n}	Fraction of Expected No. of authors	f_o	f_e	f_o-f_e	$(f_o-f_e)^2$	CHI = $(f_o-f_e)^2/ f_e$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
28	9	1.447158	13.02442	7070.341	0.00011	9	1.1	7.9	62.4	54.8
29	3	1.462398	4.387194	7762.09	0.0001	3	1.1	1.9	3.6	3.2
30	128	1.477121	189.0715	8494.592	0.001485	128	16.0	112.0	12544.0	786.1
Total	11418	32.42366	2730.845		0.23917	11418	11418	4195.9	4827660	5309.368

MLE Estimator = 2730.85/11418 = 0.24
n = 2.66
k = 0.78
df = 29
C.V. at 0.05 significant level = 42.56
Calculated chi-square value = 5309.368

CONCLUSION

Lotka's law is one of the classical laws of bibliometrics proposed in the year 1926. The relevance of this model even today holds true in many scientific disciplines. However, the testing of this law with biology literature of central universities of India is not best fitting. The reasons could be that the expectations (Table 3-Column-6) are more due to the easy availability of technology, infrastructure, learning resources, etc. Therefore, it may be concluded that the authors of biology research publications from central universities of India should come up with many more publications quantitatively with quality.

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