Lotka's Law and Authorship Distribution in Cloud Computing Research

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Abstract:

This paper examines the validity of Lotka's law to authorship distribution on the subject Area "Cloud Computing Research. In the process, we chose to consider the articles published under 2007 – 2013 for the study. Lotka's law constituting the most significant bibliometric law is applied and tested using various methods like Sen's Method, Pao's Method, and Maximum Likelihood Method and finally verified through Kolmogorov-Smirnov (KS) Test. The Hypotheses is thus tested with these measures for its validity and it is found that the values of exponent *n* and constant *c* obtained through the above said three methods proves that Lotka's Law does not hold good for the authorship pattern in cloud computing research and hence the hypotheses gets rejected.

Keywords
Lotka's law, Cloud Computing, Least Square Method, Maximum Likelihood Method, Sen's Method , Kolmogorov-Smirnov Test.

Introduction

The communication of scientific insights, experience, discussions, logic and decision making, stands on the platform of quantitative data, its mathematics and statistical interpretation. The process of theory-measurement cycle is powerful, producing authenticated and reliable inferences. The Science of measurement of bibliographies though began in 1923 , gradually got transformed into a huge area of study called Bibliometrics incorporating many Laws, and Methods. Hence, Bibliometrics, the science of quantitative study and analysis of literature have proved through Bibliometric Laws and Methods, the impact of the Researchers, their papers and thereby, the emergence of new scientific thoughts and the growth of literature. It has become such an indispensable tool, in the academic and research world today, without, which, the measurement and predictions are becoming impossible. In many of the Research Excellence Determining, the Bibliometrics has become an auxiliary tool for assessing, allocating and funding the research agencies.

The major empirical laws of bibliometrics are Lotka's Law , Zipf's Law and Bradford's Law used often in the literature to model the distribution of information phenomena. Lotka's Law is one of the most basic Law of Bibliometrics, which deals with the frequency of publication by authors in any given field. The generalized form of Lotka's law can be expressed as $$x^n y = c \qquad \ldots(1)$$

Where y is the number of authors with x articles, the exponent n and constant c are parameters to be estimated from a given set of author productivity data.

The Lotka law is named after Alfred J. Lotka when he came out with an observation that, there exists a quantitative relation among the authors and their scientific productivity during 1926. Lotka published a paper on the frequency distribution of scientific productivity using the publications appearing on Chemical Abstracts from 1907 to 1916 and proposed an inverse square law of scientific productivity. The Law states that the number of authors making x contributions is about $1/x^n$ of those making one contribution. In other words, it implies, that, most authors occur few times, and, few authors most times. It clearly states that, as the number of publications increases, the authors producing the same decreases. If N is the number of authors, Ny_1, in Lotka's equation gives the number of authors who have published a single paper each. The Lotka's equation is determined by three parameters namely, the number of scientists with minimal productivity, the maximum productivity of a scientist (X_{max}) and the characteristic exponent n. The proportion of authors that makes a single contribution is about 60%. The result can be considered as a rule of thumb even today, even after 75 years after its formulation and publication.

Literature Review

There are few landmark applications that are worth stating that discusses the situations, wherein the author productivity is far from Lotka's Law. Tsay, Ming-Yueh et.al investigated the Semiconductor Literature obtained from INSPEC Database and found that the Number of authors contributing more articles is high and which was quite opposite to the prediction of Lotka and therefore, the Fitted Curve also disproves the application of Lotka Law to the Semiconductor Research.

Rousseau discusses the issue of Lack of Standardisation in Informetric Research. He recommends that there should certainly be the measure of evenness or measure of concentration like Gini co-efficient to be a part of a standard indicator set.

Rousseau and Egghe discusses about the theory and practice of the Shifted Lotka function. The function which is put forward enables the consideration of sources with zero item and having one free parameter. It is a huge advantage when developing a theory.

Gupta B M, et al. discusses about the statistical distributions that can be used to describe the distribution of the number of authors per article. The article discusses the Inverse Gaussioan Poisson distribution. The author also finds that the geometric and truncated poisson distribution is adequate for the description of authorship. In later part, the authors investigate about the applicability of truncated binomial distribution.

Murphy applied Lotka's Law, to the humanities field and concluded that the law obeyed without applying any statistical verification measures to check the significance degrees.Schorr, makes several tests on legal medicine, map librarianship to prove the validity of Lotka's Law. Radhakrishnan and Kerniza examines the application of Lotka's Law to Computer Science Literature and opines that there is difference between the estimated and observed value and there was an emphasis that verification would be conducted on applied science and engineering. Pao employs the test of validity of Lotka's law on 48 sets of data using least square method and found that 80% of datasets confirmed to Lotka's Law in which only seven sets corroborated n=2.

There are continuous efforts that are made to study the application of Lotka's Law to many areas in many countries. Few such efforts that are worth listing are Narendra Kumar examines the applicability of Lotka's Law on research productivity of CSIR publications. Nazim and Ahmad observed the scientific productivity on Nanotechnology research that the Lotka's Law exhibits a wide difference from the observed and expected value. Zabed et al. works on Nutrition Research pertaining to Bangladesh to test the author's productivity using the K-S Goodness of Fit test and found that there is variation and however, by excluding the high productivity authors and maximum likelihood methods, that, the Lotka Law holds good for nutrition research of Bangladesh. Sen in his article puts forth the method to Derive the value of Alpha.

Allison et al. puts forth many of their interpretations on Lotka's Law. Price opines that "the total number of scientists goes up as the square, more or less, of the number of good ones'. After on, John Stewart and Paul Allison questions the consistency of Price 'Square Root Law" with Lotka's Law. *(Half of the Scientific papers are contributed by the square root of the total number of scientific authors- Price's Law)*. Later on, Michael Moravscsik and Belver Griffith explicate the difference between the Allison and Price papers. The complete round of discussion and correspondences are compiled by the Editor of Social Studies of Science and finally comes out with the explanation, that, considering only the minimum scores of prolific authors, the elite group generally contributes atleast half of the total production of papers.

Ahmed, Zabed et al. attempts to test the Lotka's Law on the field of Nutrition Research of Bangladesh. He uses Kolmogorov-Smirnov Goodness of Fit Test and finds that the Lotka's Law does not apply for Nutrition Research as suggested in Inverse Square Law. However, Using Least Square Method and Maximum Likelihood methods, the Lotka's law is found to be applicable.

(MacRoberts et al puts forth a note which examines the database used by Lotka in propounding his law, and by Price in elaborating it, and questions the validity of the generalizations drawn from it. They conclude that the data needs to be taken from multiple abstracting sources and they also opine that what portion contributed how many research publications would lead to a less of a problem.

With this background work, that, already attempted to Test the applicability of Lotka's Law, it is found that in most of the cases, the K-S Test of Goodness of Fit, Least Square methods. Many studies have also shown that the observed value deviates to the power being 3 and 4 instead of estimated 2. However, the present study aims to study the application of Lotka's Law on the author productivity of cloud computing research.

Cloud Computing Research

Cloud Computing is the buzz word and the present trend of the I.T. industry. Cloud Computing is an emerging commercial infrastructure paradigm that promises to eliminate the need for maintaining expensive computing hardware. Through the use of virtualization and resource time-sharing, cloud address with a single set of physical resources a large user base with different needs. Cloud computing enables their owners to benefit from the reduced operating costs of many applications.

Academic Institutions and Libraries are one of major beneficiaries of technology. Databases, Campus Solutions, Networks (LAN/WAN applications) are all becoming a single point access using the Cloud Computing. Therefore, it is high time, that the Academic establishments and Libraries to explore the possibilities, the pros and cons involved in getting on to the Cloud. Many National and International Cloud Sharing Debates are happening in most of the Countries, where, India is not an exception.

The authors makes an effort to evaluate the area of Cloud Computing Research by applying the Bibliometric Techniques in determining the Author productivity. Here indirectly tries to measure the intensity in which the Cloud Computing Research field is marching.

Hypotheses:

1. **The Observed Authorship Data Distribution is same as the Theoretical Authorship Data Distribution i.e., Lotka's Law**

Objective of the Study

1. By applying Inverse Square Law, Pao and Maximum Likelihood method, to arrive at the value of exponent n and constant c.
2. To determine whether the n value confirms to Lotka's Law through K-S Test.

Scope of the Study:

This is a new effort in applying, testing of Lotka Law on "Cloud Computing" research literature. The study is confined towards the Cloud computing research published worldwide during 2007-2013 as reflected in Web of Science (WoS) database. Cloud computing research being an emerging area, the author tries to evaluate the one of the Bibliometric Law on its literature. However, the paper gives scope to attempt and analyze many other Bibliometric Laws and techniques.

Methodology:

The Dataset is obtained from ISI Web of Knowledge database considers only the Authors of the Articles that appear in 3153 Articles Section from 2007 to 2013 in a Text Format Delimited by Tab. The Text File is read into a Excel Sheet which gives two columns ie. Author Names and No. of Articles. There is no fractional counting for multiple authored papers. All the authors are treated equal. The file is sorted on No. of Articles Field and counted.

Table 1 – Frequency distribution of research contributions

No. of articles (x)	No. of authors observed (y)	Percentage of authors	Total No. of contributions
1	5737	76.7594	5737
2	1114	14.9050	2228
3	325	4.3484	975
4	132	1.7661	528
5	57	0.7626	285
6	41	0.5486	246
7	25	0.3345	175
8	6	0.0803	48
9	6	0.0803	54
10	10	0.1338	100
11	5	0.0669	55
12	4	0.0535	48
13	5	0.0669	65
15	1	0.0134	15
16	2	0.0268	32
19	1	0.0134	19
22	1	0.0134	22
26	1	0.0134	26
43	1	0.0134	43
Total	7474	100	10701

The value of **exponent** *n* is calculated by the least-squares method **described by Pao** using the following formula:

$$n = \frac{N\sum XY - \sum X\sum Y}{N\sum X^2 - (\sum X)^2} \qquad \text{...(2)}$$

N = number of pairs of data

X = logarithm of x, i.e. number of articles

Y = logarithm of y, i.e. number of authors

The value of constant c is calculated using the following formula:

$$c = \frac{1}{\sum_{1}^{P-1} \frac{1}{x^n} + 1/(n-1)(P^{n-1}) + 1/2 * P^n + n/24 * (P-1)^{n+1}} \quad \text{... (3)}$$

$$\sum_{1}^{P-1} \frac{1}{x^n} = \textit{obtained by summing the first 19 terms of } \frac{1}{x^n}$$

With x = 1, 2, 3, . . . 25

Here, P = 25; n = value obtained using formula (2); x = number of articles

Deriving the value of n and c by Sen's Method

$$x^n y = c \qquad \textit{Lotka Equation}$$

Putting the value of Table-1 given in the first row in the equation (1), we get

$$1^n * 5737 = c \quad [1^n = 1]$$

$$5737 = c$$

Determining the value of n

Using the data of the second row, we can find out the value of n

Putting the data of 2nd row in equation (1), we get

$$2^n * 1114 = 5737$$

$$=> 2^n = 5737/1114$$

$$=> 2^n = 5.15$$

$$=> n \log 2 = \log 5.15$$

$$=> n * 0.301 = 0.7118$$

$$=> n = 0.7118/0.301$$

$$=> n = 2.3648$$

This paper is also applies maximum likelihood (ML) method to test Lotka's law for the Cloud Computing research output. The best-known fitting ML method currently available is a computer program called Lotka by Rousseau & Rousseau . It offers two columns for data input: source and production. Once the data are properly entered, the program returns the "best fitting" value of β (the

Lotka exponent) and *C* for the dataset.

It should be noted here that obtaining a "best fit" does not guarantee that the fitted distribution is in fact a good fit in statistical terms. To assess that one needs to perform an accepted statistical test. Pao , Nicholls and Burrell suggested using Kolmogorov-Smirnov (K-S) test, a goodness-of-fit statistical Test, to assert that the observed author productivity distribution is not significantly different from a theoretical distribution. This test is based on the maximum absolute difference between the observed and theoretical cumulative frequency distributions.

The K-S critical value at 5% level of significance is calculated as $1.36/\sqrt{\sum y}$, where $\sum y$ is the total number of authors under study. If the absolute maximum difference (D_{max}) is less than the K-S critical value, then the null hypothesis is accepted that the observed value and theoretical distribution are the same. Kolmogorov-Smirnov test at 5% significance level obtain "best fit" for the dataset.

Table 2 – Calculations of exponent *n* for *Cloud computing research*

No. of articles (x)	No. of authors observed (y)	Percentage of authors	Total No. of contributions	Log no. of articles (X)	Log no. of authors (Y)	XY	X^2
1	5737	76.7594	5737	0.0000	8.6547	0.0000	0.0000
2	1114	14.9050	6851	0.6931	7.0157	4.8629	0.4805
3	325	4.3484	7176	1.0986	5.7838	6.3542	1.2069
4	132	1.7661	7308	1.3863	4.8828	6.7690	1.9218
5	57	0.7626	7365	1.6094	4.0431	6.5070	2.5903
6	41	0.5486	7406	1.7918	3.7136	6.6538	3.2104
7	25	0.3345	7431	1.9459	3.2189	6.2636	3.7866
8	6	0.0803	7437	2.0794	1.7918	3.7259	4.3241
9	6	0.0803	7443	2.1972	1.7918	3.9369	4.8278
10	10	0.1338	7453	2.3026	2.3026	5.3019	5.3019
11	5	0.0669	7458	2.3979	1.6094	3.8593	5.7499
12	4	0.0535	7462	2.4849	1.3863	3.4448	6.1748
13	5	0.0669	7467	2.5649	1.6094	4.1281	6.5790
15	1	0.0134	7468	2.7081	0.0000	0.0000	7.3335
16	2	0.0268	7470	2.7726	0.6931	1.9218	7.6872
19	1	0.0134	7471	2.9444	0.0000	0.0000	8.6697
22	1	0.0134	7472	3.0910	0.0000	0.0000	9.5545
26	1	0.0134	7473	3.2581	0.0000	0.0000	10.6152
43	1	0.0134	7474	3.7612	0.0000	0.0000	14.1466
Total	7474	100	138822	41.08758	48.4970	63.7293	104.1607

Results of the study:

Table-1 shows that almost (5737) 76% produced single article, (1114)14% produced 2 articles, (325) 4% produced 3 articles, (132) 1.7 % produced 4 articles, (57) 0.7% produced 5 articles, (41) 0.5% produced 6 articles, (25) 0.33% produced 7 Articles and the authors produced more than 8 articles is 0.0.08% and gradually, the number of authors producing 16 and more articles is 0.002%. We can observe that the authors contributing 17 and more papers to the Cloud Computing Research is as less as 0.0134%.

From Table 2, the estimated valued n for the dataset is calculated using formula (2). The value of *n* of the Cloud Computing Research through Least Square Method produces a value of *n*=2.6777

$$n = \frac{N\sum XY - \sum X \sum Y}{N\sum X^2 - (\sum X)^2}$$

$$= \frac{19 * 63.7293 - 41.0875 * 48.4970}{19 * 104.1607 - 41.0875^2}$$

$$= -\frac{781.7631}{290.8707}$$

$$= -2.6877$$

The constant *c* for the dataset is calculated using the formula (3) and the value of *c* =0.7826. Applying the value of *n* and *c* to the generalized Lotka's equation, it is found that the value of Y decreases with the increase of the value of X.

$$c = \frac{1}{\sum_1^{P-1} \frac{1}{x^n} + {}^1/_{(n-1)(P^{n-1})} + {}^1/_{2 * P^n} + {}^n/_{24 * (P-1)^{n+1}}}$$

$$= \frac{1}{\sum_1^{19} {}^1/_{x^{2.6877}} + {}^1/_{1.6877 * 20^{1.6877}} + {}^1/_{2 * 20^{2.6877}} + {}^{2.6877}/_{24 * 19^{3.6877}}}$$

$$= \frac{1}{1.2739 + 0.0037 + 0.000159 + 0.000001553}$$

$$= \frac{1}{1.2777}$$

$$= 0.7826$$

The *n* value was also calculated by maximum likelihood method using *Lotka* program. The β-value (the Lotka exponent) is **2.7865 and constant** C= 0.7997 for the dataset.

Results from the Pao's Method:

The obtained calculated value of *n* being 2.6877 and the value of *c* being 0.7826 suggests that, the, Lotka's Law is observed to be slightly deviating from the Linear Line. It is observed that there are x and y co-ordinates for the higher value of x correspondingly, an higher value of y also which, summarizes that there are more number of authors contributing more articles which is reverse to the concept of Lotka Law. This is the case with higher values of x and y, if we truncate these values, Lotka's Law is observed to be valid by applying the value of *n* and *c*. The Y-intercept (2.6877) increases as X increases.

Figure 1 – Fitted linear line for authorship distribution in *Cloud Computing Research*

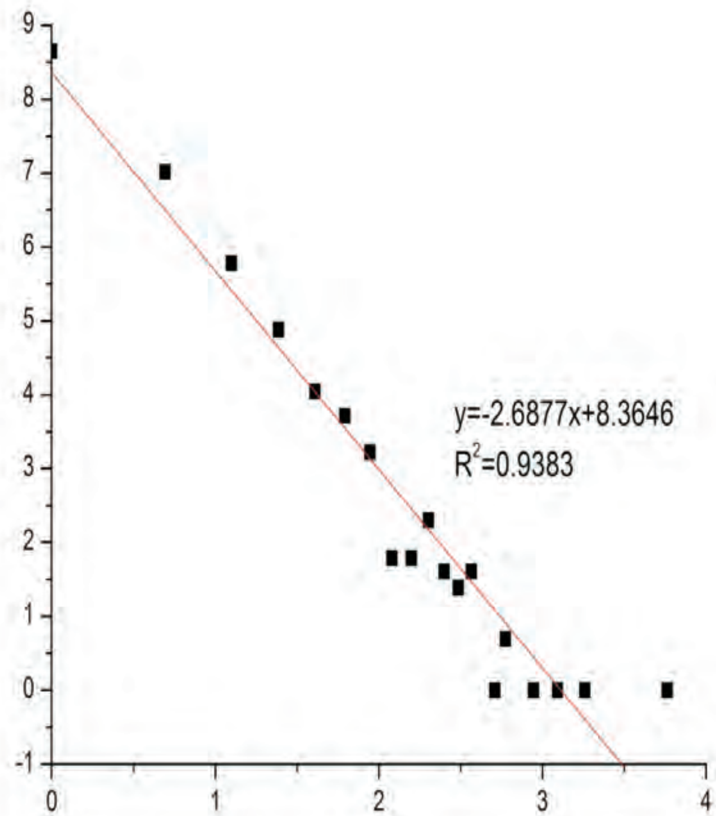

Figure-1 clearly shows the Linear relationship of the Variable x, y through the Scatter Plot. The graph represents the straight line y=mx+c, where the slope m=2.6877 and c = 8.3646 and a R^2 value of 0.9383. This infers that the data set fall into a linear relationship where the value of variable y decreases with the increase in the value of x. Therefore, the graph clearly indicates the validity of the Lotka's Law in case of truncating the higher values of x and y coordinates.

Table 3 – Fitted Lotka distribution with LS *n* =2.6877, ML *n* =2.7404, SM *n* =2.3648

No of Acticles (x)	No. of authors observed (y)	Log no. of articles (X)	Log no. of authors (Y)	Y=nX+C	Expected with LS n=2.6877	LS n=2.6877 (standardized)	Expected with ML n=2.7404	ML n=2.7404 (standardized)	Expected with SM n=2.3648	SM n=2.3648(standardized)
1	5737	0.0000	8.6547	8.3646	4292.39	5872.86	5737.00	5939.18	5737.0	5400.27
2	1114	0.6931	7.0157	6.5016	666.23	911.53	858.50	888.76	1113.8	1048.43
3	325	1.0986	5.7838	5.4119	224.05	306.54	282.61	292.57	426.96	401.90
4	132	1.3863	4.8828	4.6387	103.41	141.48	128.47	133.00	216.24	203.55
5	57	1.6094	4.0431	4.0389	56.76	77.67	69.70	72.16	127.57	120.09
6	41	1.7918	3.7136	3.5489	34.77	47.58	42.29	43.78	82.89	78.03
7	25	1.9459	3.2189	3.1346	22.98	31.44	27.72	28.70	57.57	54.19
8	6	2.0794	1.7918	2.7757	16.05	21.96	19.22	19.90	41.98	39.52
9	6	2.1972	1.7918	2.4591	11.69	16.00	13.92	14.41	31.78	29.91
10	10	2.3026	2.3026	2.1759	8.81	12.05	10.43	10.80	24.77	23.31
11	5	2.3979	1.6094	1.9198	6.82	9.33	8.03	8.32	19.77	18.61
12	4	2.4849	1.3863	1.6859	5.40	7.38	6.33	6.55	16.09	15.15
13	5	2.5649	1.6094	1.4708	4.35	5.96	5.08	5.26	13.32	12.54
15	1	2.7081	0.0000	1.0862	2.96	4.05	3.43	3.55	9.49	8.94
16	2	2.7726	0.6931	0.9127	2.49	3.41	2.88	2.98	8.15	7.67
19	1	2.9444	0.0000	0.4508	1.57	2.15	1.80	1.86	5.43	5.11
22	1	3.0910	0.0000	0.0568	1.06	1.45	1.20	1.24	3.84	3.61
26	1	3.2581	0.0000	-0.3922	0.68	0.92	0.76	0.79	2.59	2.43
43	1	3.7612	0.0000	-1.7444	0.17	0.24	0.19	0.20	0.79	0.74
Total	7474	41.0876	48.4970		5462.65	7474	7219.57	7474	7940	7474

Table 3: Displays the testing of *n* value in different modes. They are through Least Square Method, Maximum Likelihood Method, and Sen's Method. The values of *n* obtained are n=2.6877 (LS), n=2.740 (ML) and n=2.3648(SM). When the number of authors expected from these methods compared with each other, it is clear from the above table that the values of LS < ML < SM. From the Table-3, we can infer that Maximum Likelihood Method is closer to the observed values of Cloud

Computing Research as compared with Least Square Method and Sen's Method.

Table 4 – Kolmogorov-Smirnov test for n = 2

No. of articles (x)	Observed frequency of authors	Observed cumulative frequency of authors	Theoretical frequency of authors	Theoretical cumulative frequency of authors	Difference
1	0.7676	0.7676	0.6079	0.6079	0.1597
2	0.1491	0.9167	0.152	0.7599	-0.0029
3	0.0435	0.9602	0.0675	0.8274	-0.0240
4	0.0177	0.9779	0.038	0.8654	-0.0203
5	0.0076	0.9855	0.0243	0.8897	-0.0167
6	0.0055	0.9910	0.0169	0.9066	-0.0114
7	0.0033	0.9943	0.0124	0.919	-0.0091
8	0.0008	0.9951	0.0095	0.9285	-0.0087
9	0.0008	0.9959	0.0075	0.936	-0.0067
10	0.0013	0.9972	0.0061	0.9421	-0.0048
11	0.0007	0.9979	0.005	0.9471	-0.0043
12	0.0005	0.9984	0.0042	0.9513	-0.0037
13	0.0007	0.9991	0.0036	0.9549	-0.0029
15	0.0001	0.9992	0.0027	0.9576	-0.0026
16	0.0003	0.9995	0.0024	0.96	-0.0021
19	0.0001	0.9996	0.0017	0.9617	-0.0016
22	0.0001	0.9997	0.0013	0.963	-0.0012
26	0.0001	0.9998	0.0009	0.9639	-0.0008
43	0.0001	0.9999	0.0003	0.9642	-0.0002

The D_{Max} from the Table-4 is 0.1597 and is greater than the Critical Value of Kolmogorov-Smirnov Test at the level of significance 0.05 is 0.0157 determined with Lotka's exponent n=2 and hence doesn't supports for the consideration of Hypotheses i.e., the Observed Authorship Data Distribution doesn't holds good for the Lotka's Law.

Similarly a Kolmogorov-Smirnov Test is applied for the fitness of the Lotka's law for the values of Lotka's exponents obtained from LS and ML methods. The results indicate that the values of D-Max, i.e. 0.0276 and 0.0306 determined with Lotka's exponents, i.e. n=2.6877 (LS) and n=2.7404 (ML) respectively. The critical value determined at the 0.005 level of significance is 0.0157 which is lesser than the D-Max value and hence does not supports for the consideration of Hypotheses i.e., the Observed Authorship Data Distribution does not holds good for the Lotka's Law and therefore, the Lotka's Law for the Cloud Computing Research literature is not accepted for the Authorship Distribution.

Conclusion:

The Authorship Data Distribution at the Cloud Computing Research is being tested for the application of the Lotka's Law and the Hypotheses assumed is that the Observed Data Distribution is same as the theoretical Data Distribution. The value *n* is determined through various methods like Least Square Method, Maximum Likelihood and Sen's Method. The calculated data is verified through Kolmogorov Smirnov Test for various values of *n*. It is found that Lotka's Law does not hold good for the all the three methods used with KS-Test. The observed distribution is also tested against the inverse square law using the exponent n=2; it is found that Cloud Computing Literature do not confirm to Lotka's law.

As this is a primary effort in just finding out the applicability of Lotka's law to a small piece of sample with broad conditions of considering equal weightage to all contributors, the effort can be extended to multiple authors, authorship pattern considering other publication types, author affiliations etc.,

References

Bradford, S. (1950). *Documentation*. Washington: D.C. Public Affairs Press.

Burrell, Q. (1994). The Kolmogorov-Smirnov Test and Rank Frequency Distributions. *Journal of the American Society for Information Science*, *45*(1), 59.

Gupta, B., Kumar, S., & Rousseau, R. (1998). Applicability of Selected Probability Distributions to the number of authors per article in theoretical population Genetics. *Scientometrics*, *42*(3), 325–334.

Hulmes, E. (1923). *Statistical bibliography in relation to the growth of modern civilization*. Grafton: Grafton.

Lotka, A. (1926). The frequency distribution of scientific productivity. *Journal of the Washington Academy of Sciences*, *16*(2), 317–323.

MacRoberts, H. (1982). A Re-evaluation of Lotka's Law of Scientific Productivity. *Social Studies of Science*, *12*, 443–450.

Mohammad, N., & Ahmad, M. (2008). A bibliometric analysis on a Nanatechnology Research. *Annals of Library and Information Science*, *55*, 292–299.

Murphy, L. (1973). Lotka's Law in the Humanities. *Journal of American Society for Information Science*, *24*(6), 461–462.

Narendra, K. (2010). Applicability to Lotka's Law to research productivity of CSIR, India. *Annals of Library and Information Studies*, *57*, 7–11.

Nicholls, P. (1989). Bibliometric modeling processes and the empirical validity of Lotka's law. *Journal of the American Society for Information Science*, *40*, 379–385.

Pao, M. L. (1985). Lotka's Law?: A Testing procedure. *Information Processing & Management*, *21*, 305–320.

Pao, M. L. (1986). An Empirical Examination of Lotka's Law. *Journal of the American Society for Information Science*, *37*(1), 26–33.
Paul Allison, & Derek Price, D. S. (1976). Lotka'sLaw?: A Problem in its Interpretation and Application. *Social Studies of Science*, *6*(2), 269–276.
Pritchard, A. (1969). Statistical bibliography or bibliometrics? *Journal of Documentation*, *25*, 348–349.
Radhakrishnan, T., & Kernizan. (1979). Lotka's Law and Computer Science Literature. *Journal of American Society for Information Science*, *30*(1), 51–54.
Rousseau, R. (2002). Lack of standardization in informetric research. Comments on "Power Laws of Research Output. Evidence for Journals of Economics" by Matthias Sutter and Martin G. Kocher. *Scientometrics*, *55*(2), 317–327.
Rousseau, R., & Egghe, L. (2012). Theory and Practice of the shifted Lotka function. *Scientometrics*, *91*, 295–301.
Rousseau, R., & Rousseau, R. (2000). Lotka: A program to fit a Power Law Distribution to observed Frequency Data. *Cybermetrics*, *4*(1), 4.
Schorr, A. (1974). Lotka's Law and Library Science. *Research Quarterly*, *14*, 32–33.
Sen, B. (2010). Lotka's Law: A View point. *Annals of Library and Information Studies*, *57*, 166–167.
Sobrino, M., Caldes, A., & Guerrero, A. (2008). Lotka law applied to the scientific production of information science area. *Brazilian Journal of Information Science*, *2*, 16–30.
Tsay, M.-Y., Jou, S.-J., & Ma, S.-S. (2000). A Bibliometric Study of Semiconductor Literature-1978-1997. *Scientometrics*, *49*(3), 491–509.
Wikipeadia. (2012a). Bibliometrics. Retrieved from http://en.wikipedia.org/wiki/Bibliometrics
Wikipeadia. (2012b). Lotka's law. Retrieved from http://en.wikipedia.org/wiki/Lotka%27s_law
Zabed, A., Rahman, S., & Anisur. (2009). Lotka's Law and authorship distribution in nutrition research in Bangladesh. *Annals of Library and Information Studies*, *56*, 95–102.
Zipf, G. (1949). *Human behaviour and the principle of least effort*. Cambridge: Addison-Wesley.