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Lotka's Law and Author Productivity in HIV/AIDS Vaccine Research: Evidence from PubMed (2001-2020)

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ABSTRACT

This study aims to analyze the productivity patterns of authors in HIV AIDS vaccines using publications available in PubMed from 2001 to 2020 based on Lotka's Law. Lotka's Law of scientific productivity provides a platform for studying inequality in authors' productivity patterns in a given field and over a specified period. This study covers all the journal articles on HIV AIDS Vaccine literature over Twenty years (2001-2020) in PUBMED, 10268 articles were reported to have been published during this period. The findings of the study reveal that in the productivity distribution for authors on the subject of HIV AIDS Vaccine, only co-authors and non-collaborative authors' categories fit in Lotka's Law, whereas all authors and first-author categories differ from the distribution of Lotka's inverse square law. The Lotka's law on authorship productivity of E-Journals of Health Science have been tested to confirm the law's applicability to the present data set. 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 α = 2. It is found that the inverse square law of Lotka follows as such

KEYWORDS: Lotka's Law, Productivity Patterns, Co-authorship Index (CAI), Kolmogorov Smirnov Test (K-S Test), Collaborative Co-Efficient (CC). Bibliometric Study, Scietometrics, PUBMED.

INTRODUCTION

Bibliometric studies are utilized across various fields to measure the growth of disciplines, including Library and Information Science. Accurate data collection from reliable sources is crucial in these studies, as four key components—publication form, authorship pattern, year, and place of publication—are examined to understand the expansion of knowledge in a specific area. This method is effective in assessing the development of information resources, which are essential for teaching, learning, and research for faculty, students, and scholars. Consequently, it promotes sustainable growth in research and development within the subject. Bibliometrics, recognized globally as an interdisciplinary field, is rapidly evolving in information science due to its critical examination of information properties and behavior.

This study focuses on HIV/AIDS vaccine literature available in the PubMed database from 2001 to 2020, covering a span of 20 years.

LAW OF BIBLIOMETRICS

Bibliometrics is a field that applies mathematical and statistical methods to analyze scholarly publications (Thompson & Walker, 2015). It originated with the foundational laws established by Alfred Lotka and Samuel Bradford, which describe patterns in scientific productivity and journal distribution (Thompson & Walker, 2015). The three main bibliometric laws are Lotka's Law, Bradford's Law, and Zipf's Law (Latief, 2014) (Coelho et al., 2023). These laws can be applied to identify patterns in academic structures, such as research productivity and institutional influence (Machado Junior et al., 2016). Bibliometrics encompasses various aspects, including author productivity, citation analysis, and keyword frequency (Latief, 2014) (Cleber-Da-Silva André et al., 2014). The field has numerous applications in medical sciences and healthcare, with bibliometric parameters potentially influencing grant funding decisions and academic promotions (Thompson & Walker, 2015). However, it is crucial to understand the limitations and appropriate uses of bibliometric data to ensure accurate interpretation and application in research and evaluation contexts (Thompson & Walker, 2015).

Lotka's Law of Scientific Productivity

Lotka's law, which describes the distribution of scientific productivity among authors, has been the subject of several studies. While some research has failed to support the law's applicability (Friedman, 2015; Thamaraiselvi et al., 2020), others have used it to examine authorship patterns in specific fields (Sivakumar et al., 2013). The law states that the number of authors publishing a certain number of articles is a fixed ratio to those publishing a single article (Friedman, 2015). However, modern analysis has revealed potential issues with Lotka's original methodology, including data truncation and the use of log-log plot regression, which is now considered unreliable (Bensman & Smolinsky, 2016). Various statistical methods, such as the general power method, inverse square method, and goodness-of-fit tests, have been employed to verify the law's applicability in different contexts (Thamaraiselvi et al., 2020). Despite its limitations, Lotka's law remains a significant tool for analyzing scientific productivity patterns.

OBJECTIVE OF THE STUDY

- ✓ To measure and calculate the Relative Growth Rate and Doubling Time Publications.
- ✓ To find out Authorship Pattern: Journals wise.
- ✓ To indicate Co-Authorship.
- ✓ To find out Authorship Productivity Pattern.
- ✓ To observe the Chi-Square Test for Productivity of Authors.
- ✓ To examine the validity of KS Test of goodness of fit.
- ✓ To observe the Productivity Index (PI).
- ✓ The analyses the research trend with Co-Efficient for Collaborative Authors.

METHODOLOGY

The present study contains a total of 10268 article were available in PubMed database during 2001-2010. Data collected form the PubMed Database. Total 10268 articles data received are tabulated into different criteria for analysis. The Microsoft-excel was used to draw the statistical inferences of the data.

ANALYSIS AND INTERPRETATION OF THE RESULT

Relative growth rate and Doubling Time publications

In order to identify the relative growth rate, the researcher has adopted a model developed by Mahapatra. The relative growth rate is the increase in the number of publications per unit of time. The mean relative growth rate, R-(1-2) over a specified period of interval can be calculated from the following equation.

$$R(1\text{-}2)=\frac{W2-W1}{T2-T1}$$

Where,

R(1-2)= Mean Relative Growth over the specified period interval;

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.

R(a) = Relative Growth Rate Per Unit Publication per unit of time (Year)

1. Doubling Time

Doubling time for publication Dt(a)= 0.693/R(a)

Table no. 1 Relative growth rate and Doubling Time of Publication

Sr.No.	Year	TP	Cumulative Paper	Loge 1p	Loge 2p	[R (P)]	Mean[R (P)]	[Dt(p)]	Mean [Dt (p)]
1	2001	557	557		6.3226				
2	2002	570	1127	6.3226	7.0273	0.705		0.983	
3	2003	642	1769	7.0273	7.4782	0.451		1.537	
4	2004	649	2418	7.4782	7.7907	0.313		2.217	
5	2005	761	3179	7.7907	8.0643	0.274		2.533	
6	2006	823	4002	8.0643	8.2946	0.230		3.010	
7	2007	823	4825	8.2946	8.4816	0.187		3.706	
8	2008	859	5684	8.4816	8.6454	0.164		4.230	
9	2009	894	6578	8.6454	8.7915	0.146		4.744	
10	2010	976	7554	8.7915	8.9298	0.138	0.2897	5.009	3.1077
11	2011	1011	8565	8.9298	9.0554	0.126		5.517	
12	2012	1001	9566	9.0554	9.1660	0.111		6.270	
13	2013	1068	10634	9.1660	9.2718	0.106		6.548	

14	2014	1218	11852	9.2718	9.3803	0.108		6.391	
15	2015	1248	13100	9.3803	9.4804	0.100		6.922	
16	2016	1284	14384	9.4804	9.5739	0.094		7.411	
17	2017	1141	15525	9.5739	9.6502	0.076		9.078	
18	2018	1122	16647	9.6502	9.7200	0.070		9.931	
19	2019	1152	17799	9.7200	9.7869	0.067		10.357	
20	2020	1281	19080	9.7869	9.8564	0.069	0.0927	9.971	7.8397

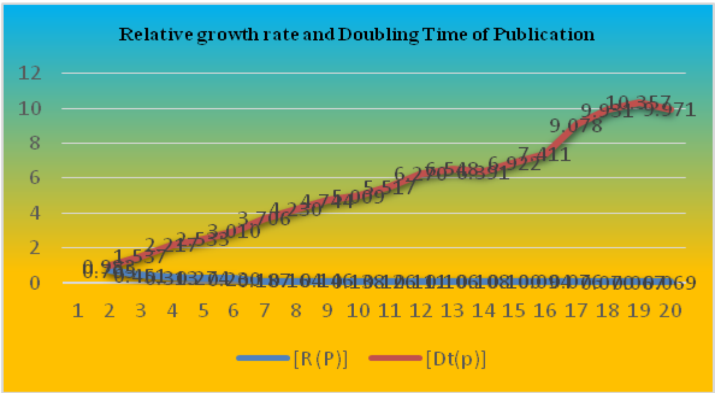


Figure No 1. Relative Growth Rate and Doubling Time of Publications

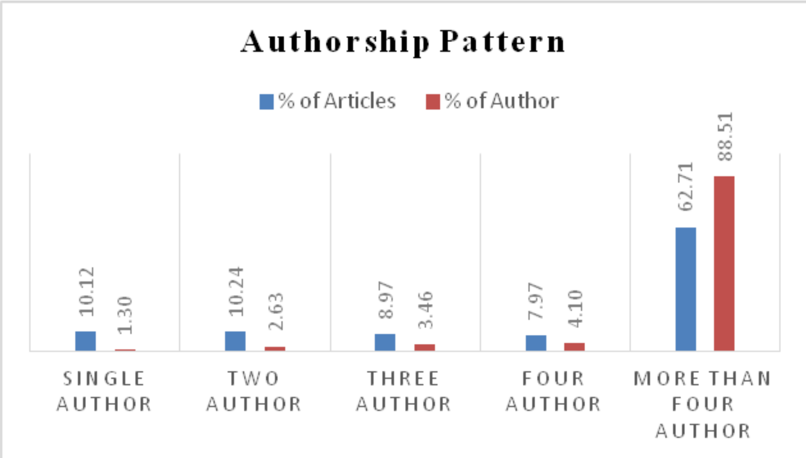
The Relative Growth Rate [R(P)] and Doubling Time [Dt(P)] of publications are derived and presented in table no 1 and figure no.1. It can be noticed that Relative Growth Rate of publication [R(P)] decreased from the rate 0.705 in 2002 to 0.69 in 2020. The mean Relative Growth for the first ten seven year (i.e. 2002 to 2010) showed a growth rate of 0.289 whereas the mean relative growth rate for the last ten year (i.e. 2011 to 2020) reduced to 0.092. The corresponding Doubling Time for different year [Dt(P)] gradually increased from 0.983 in 2002 to 9.971 in 2020.

The mean Doubling Time for the first ten year (i.e. 2001 to 2010) was only 3.107 which were increased to 7.839 during the last ten year (i.e. 2011 to 2020). Thus as the rate of growth of publication was decreased, the corresponding Doubling Time was increased.

2. Authorship Pattern

Table no. 2. Authorship pattern

Sr.No.	No. of Article	Total no of Author	% of Articles	% of Author	% cumulative of Articles	% cumulative of Authors
1	1930	1930	10.12	1.30	10.12	1.30
2	1954	3908	10.24	2.63	20.36	3.93
3	1711	5133	8.97	3.46	29.33	7.39
4	1520	6080	7.97	4.10	37.30	11.49
4+	11965	131311	62.71	88.51	100	100
Total	**19080**	**148362**	**100**	**100**		



Authorship pattern among PubMed database of HIV AIDS Vaccine is given in the Table 2 and Figure no.2. Single authored papers contributions are 1930 (1.3%). Two authored papers account for 1954 (10.24%) followed by three authored papers 1711 (8.97%), four authored papers 1520 (7.97%) more than four authored papers 11965 (62.71%). The authorship pattern reveals a remarkable difference between the number of single author and multiple authors.

3. Authorship Productivity Pattern

The productivity of authors was measured in items of the number of times a particular author was article during 2001-2020. The study revealed that few authors had been cited more number of times. The details of number of articles received by the authors are providing in table no.3 and figure no. 3.

Table no.3 Authorship Productivity pattern

Number of Article (n)	Observed authors with 'n' Article (an)	Observed % of authors (100Xan/a1)	Expected number of authors (an=a1/n2)	Expected % authors predicted by Lotka's (100/n2)
Single	1930	100	1930	100
Two	1954	101.24	488.5	25
Three	1711	88.65	190.1111	11.11111
Four	1520	78.75648	95	6.25
Five	1357	70.31088	54.28	4
Six	1292	66.94301	35.88889	2.777778
Seven	1314	68.0829	26.81633	2.040816
Eight	1113	57.66839	17.39063	1.5625
Nine	1102	57.09845	13.60494	1.234568
Multi	5929	307.2021		

Table no.3 shows that, the productivity of authors was measured in terms of the number of times a particular author was cited during 2001-2020. Out of the total 19080 articles, minimum numbers (57) of authors were Nine and maximum (1930) number of authors was only once. The study revealed that few authors had been cited more number of times. The well known Lotka's law as applied to authors' productivity, it revealed that the observed percentage of authors varied from the expected percentage of authors as predicated by applying Lotka's equation.

4. Distribution of Document

Table no. 4 Distribution of Document

Sr. No	Documents written	No of Authors	Percentage	Total contribution	Percentage
1	1	19606	64.66	19606	24.59
2	2	4529	14.94	9058	11.36
3	3	1880	6.20	5640	7.07
4	4	1074	3.54	4296	5.39
5	5	680	2.24	3400	4.26
6	6	492	1.62	2952	3.70
7	7	337	1.11	2359	2.96
8	8	264	0.87	2112	2.65
9	9	185	0.61	1665	2.09
10	10	156	0.51	1560	1.96
11	11	145	0.48	1595	2.00
12	12	104	0.34	1248	1.57
13	13	110	0.36	1430	1.79
14	14	70	0.23	980	1.23
15	15	64	0.21	960	1.20
16	16	52	0.17	832	1.04
17	17	51	0.17	867	1.09
18	18	40	0.13	720	0.90
19	19	36	0.12	684	0.86
20	20	33	0.11	660	0.83
21	21	27	0.09	567	0.71
22	22	27	0.09	594	0.75
23	23	23	0.08	529	0.66
24	24	25	0.08	600	0.75
25	25	18	0.06	450	0.56
26	26	16	0.05	416	0.52
27	27	19	0.06	513	0.64
28	28	12	0.04	336	0.42
29	29	16	0.05	464	0.58
30	30	16	0.05	480	0.60
31	31	10	0.03	310	0.39

32	32	16	0.05	512	0.64
33	33	8	0.03	264	0.33
34	34	12	0.04	408	0.51
35	35	12	0.04	420	0.53
36	36	10	0.03	360	0.45
37	37	8	0.03	296	0.37
38	39	10	0.03	390	0.49
39	40	4	0.01	160	0.20
40	41	4	0.01	164	0.21
41	42	3	0.01	126	0.16
42	43	3	0.01	129	0.16
43	44	5	0.02	220	0.28
44	45	4	0.01	180	0.23
45	46	5	0.02	230	0.29
46	47	2	0.01	94	0.12
47	48	3	0.01	144	0.18
48	49	5	0.02	245	0.31
49	50	4	0.01	200	0.25
50	51	4	0.01	204	0.26
51	52	1	0.00	52	0.07
52	53	4	0.01	212	0.27
53	54	4	0.01	216	0.27
54	55	2	0.01	110	0.14
55	56	2	0.01	112	0.14
56	57	3	0.01	171	0.21
57	58	1	0.00	58	0.07
58	59	1	0.00	59	0.07
59	60	3	0.01	180	0.23
60	61	1	0.00	61	0.08
61	62	3	0.01	186	0.23
62	63	1	0.00	63	0.08
63	64	2	0.01	128	0.16
64	65	2	0.01	130	0.16
65	66	4	0.01	264	0.33
66	67	1	0.00	67	0.08
67	68	4	0.01	272	0.34
68	71	3	0.01	213	0.27
69	73	2	0.01	146	0.18
70	75	1	0.00	75	0.09

71	76	1	0.00	76	0.10
72	77	1	0.00	77	0.10
73	78	1	0.00	78	0.10
74	79	2	0.01	158	0.20
75	80	1	0.00	80	0.10
76	81	1	0.00	81	0.10
77	83	2	0.01	166	0.21
78	87	1	0.00	87	0.11
79	92	3	0.01	276	0.35
80	93	1	0.00	93	0.12
81	97	1	0.00	97	0.12
82	98	1	0.00	98	0.12
83	100	2	0.01	200	0.25
84	102	1	0.00	102	0.13
85	103	1	0.00	103	0.13
86	104	1	0.00	104	0.13
87	105	1	0.00	105	0.13
88	110	1	0.00	110	0.14
89	115	1	0.00	115	0.14
90	116	1	0.00	116	0.15
91	117	1	0.00	117	0.15
92	119	1	0.00	119	0.15
93	123	1	0.00	123	0.15
94	130	1	0.00	130	0.16
95	131	1	0.00	131	0.16
96	137	1	0.00	137	0.17
97	146	1	0.00	146	0.18
98	181	1	0.00	181	0.23
99	193	1	0.00	193	0.24
100	202	1	0.00	202	0.25
101	211	1	0.00	211	0.26
102	307	1	0.00	307	0.39
	6400	**30321**	**100.00**	**79723**	**100.00**

Table no4 shows that The total number of authors is 30,321, contributing to a total of 79,723 documents. The majority of contributions are made by authors with fewer documents, demonstrating a high skew towards lower-document authors.

This distribution aligns with Lotka's Law, which suggests that the number of authors making n contributions is about 1/n^2 of those making one contribution, highlighting a few prolific authors and a larger number of occasional contributors.

This detailed understanding of document distribution can inform strategies for resource allocation, author engagement, and collaborative research efforts.

5. Chi-Square Test for Productivity of Authors

Table no. 5 Chi-Square Test for productivity of Author

No. of papers	Observed No of Author (FI)	Expected Author (Pi)	Fi-Pi	(Fi-Pi)*(fi-pi)
1	19606	19606	0	0
2	4529	4902	-373	138756
3	1880	2178	-298	89069
4	1074	1225	-151	22914
5	680	784	-104	10866
6	492	545	-53	2768
7	337	400	-63	3984
8	264	306	-42	1793
9	185	242	-57	3255
10	156	196	-40	1605
11	145	162	-17	290
12	104	136	-32	1034
13	110	116	-6	36
14	70	100	-30	902
15	64	87	-23	535
16	52	77	-25	604
17	51	68	-17	284
18	40	61	-21	421
19	36	54	-18	335
20	33	49	-16	256
21	27	44	-17	305
22	27	41	-14	182
23	23	37	-14	198
24	25	34	-9	82
25	18	31	-13	179
26	16	29	-13	169
27	19	27	-8	62

28	12	25	-13	169
29	16	23	-7	53
30	16	22	-6	33
31	10	20	-10	108
32	16	19	-3	10
33	8	18	-10	100
34	12	17	-5	25
35	12	16	-4	16
36	10	15	-5	26
37	8	14	-6	40
39	10	13	-3	8
40	4	12	-8	68
41	4	12	-8	59
42	3	11	-8	66
43	3	11	-8	58
44	5	10	-5	26
45	4	10	-6	32
46	5	9	-4	18
47	2	9	-7	47
48	3	9	-6	30
49	5	8	-3	10
50	4	8	-4	15
51	4	8	-4	13
52	1	7	-6	39
53	4	7	-3	9
54	4	7	-3	7
55	2	6	-4	20
56	2	6	-4	18
57	3	6	-3	9
58	1	6	-5	23
59	1	6	-5	21
60	3	5	-2	6
61	1	5	-4	18
62	3	5	-2	4
63	1	5	-4	16
64	2	5	-3	8
65	2	5	-3	7

66	4	5	-1	0
67	1	4	-3	11
68	4	4	0	0
71	3	4	-1	1
73	2	4	-2	3
75	1	3	-2	6
76	1	3	-2	6
77	1	3	-2	5
78	1	3	-2	5
79	2	3	-1	1
80	1	3	-2	4
81	1	3	-2	4
83	2	3	-1	1
87	1	3	-2	3
92	3	2	1	0
93	1	2	-1	2
97	1	2	-1	1
98	1	2	-1	1
100	2	2	0	0
102	1	2	-1	1
103	1	2	-1	1
104	1	2	-1	1
105	1	2	-1	1
110	1	2	-1	0
115	1	1	0	0
116	1	1	0	0
117	1	1	0	0
119	1	1	0	0
123	1	1	0	0
130	1	1	0	0
131	1	1	0	0
137	1	1	0	0
146	1	1	0	0
181	1	1	0	0
193	1	1	0	0
202	1	0	1	0
211	1	0	1	0

307	1	0	1	1

The table no. 5 illustrate that Chi Square distribution is very important because many test statistics are approximately distributed as Chi Square. Two of the more common tests using the Chi Square distribution are tests of deviations of differences between theoretically expected and observed frequencies (one-way tables) and the relationship between categorical variables (contingency tables). Numerous other tests beyond the scope of this work are based on the Chi Square distribution. Chi-square test was conducted to study whether credibility of authors is dependent on their contributions in different years. The Pearson Chi-square value 878.24 with 80 degrees of freedom is found to be insignificant at 0.05 level of significance (p>0.05). Therefore, we may conclude that the attributes credibility of authors is independent of the contributions in year. The measure of association is found to be 282184 which highest.

To perform the Chi-square test, we will use the following formula:

$$\chi^2 = \sum \frac{(Fi-Pi)^2}{Pi}$$

Given that the sum of the differences squared is provided in the table, we calculate the Chi-square value.
To determine the significance of this Chi-square statistic, we need to compare it to a critical value from the Chi-square distribution table at the desired confidence level (e.g., 0.05) and with the appropriate degrees of freedom (df).
The degrees of freedom (df) for a Chi-square goodness-of-fit test is calculated as:
df=number of categories−1df = \text{number of categories} - 1df=number of categories−1
In this case, the number of categories is the number of rows (or unique counts of papers). We have 81 rows, so:

df=81−1=80df = 81 - 1 = 80df=81−1=80

Using a Chi-square distribution table, we find the critical value for df=80df = 80df=80 at a significance level of 0.05. For large degrees of freedom, the critical value can be found using statistical software or Chi-square distribution tables.

For df=80df = 80df=80 and α=0.05\alpha = 0.05α=0.05:

X critical2≈101.88\chi^2_{critical} \approx 101.88χcritical2≈101.88

- **If χ2\chi^2χ2 > critical value**: There is a significant difference between observed and expected frequencies. We reject the null hypothesis.
- **If χ2\chi^2χ2 <= critical value**: There is no significant difference between observed and expected frequencies. We fail to reject the null hypothesis.

Given that the calculated Chi-square value (878.24) is much greater than the critical value (101.88), we **reject the null hypothesis**. This indicates that there is a significant difference between the observed and expected author frequencies, suggesting that the distribution of authorship does not follow the expected theoretical model (e.g., Lotka's Law).

6. KS Test of goodness of fit

The productivity of the paper contribution of the medicine journal was verified to be in conformity with Lotka's inverse square law using Pao's method. Table No. 6. KS Test of goodness of fit.

Pao (1985) suggests the K-S test, a goodness-of-fit statistical test to assert that the observed author productivity distribution is not significantly different from an expected distribution. The hypothesis concerns a comparison between observed and expected frequencies. The test allows the determination of the associated probability that the observed maximum deviation occurs within the limits of chance. The maximum deviation between the cumulative proportions of the observed and expected frequency is determined by the following formula

$$D = \max |F_o(x) - F_e(x)|$$

F0(x) = theoretical cumulative frequency Sn(x) = observed cumulative frequency The test is performed at the 0.05 or at the 0.01 level of significance. When sample size is greater than 35, the critical value of significance is calculated by the following formula:

The critical value at the 0.05 level of significance: $\frac{1.36}{\sqrt{\sum y}}$

The critical value at the 0.01 level of significance: $\frac{1.63}{\sqrt{\sum y}}$

$\sum y$ = the total population under study

Total number of authors = 30321

Table no. 6 KS Test of goodness of fit

(X) No. of Paper	(Y) No. of Authors	Log (X)	Log (Y)	Log (XY)	Log (XX)	Observed Authors	Cumulative Observed Authors	Expect Authors	Expect Authors	Cumulative expected Authors	D-Max
1	19606	0	4.292389	0	0	0.964	0.964	4354	0.612	0.612	-0.352
2	4529	0.30103	3.656002	1.100566	0.090619	0.223	1.187	1089	0.153	0.765	-0.422
3	1880	0.477121	3.274158	1.56217	0.227645	0.092	1.280	484	0.068	0.833	-0.446
4	1074	0.60206	3.031004	1.824846	0.362476	0.053	1.332	272	0.038	0.872	-0.461
5	680	0.69897	2.832509	1.979839	0.488559	0.033	1.366	174	0.024	0.896	-0.470
6	492	0.778151	2.691965	2.094756	0.605519	0.024	1.390	121	0.017	0.913	-0.477
7	337	0.845098	2.52763	2.136095	0.714191	0.017	1.407	89	0.012	0.926	-0.481
8	264	0.90309	2.421604	2.186926	0.815572	0.013	1.420	68	0.010	0.935	-0.484
9	185	0.954243	2.267172	2.163432	0.910579	0.009	1.429	54	0.008	0.943	-0.486
10	156	1	2.193125	2.193125	1	0.008	1.436	44	0.006	0.949	-0.487
11	145	1.041393	2.161368	2.250833	1.084499	0.007	1.444	36	0.005	0.954	-0.490
12	104	1.079181	2.017033	2.176745	1.164632	0.005	1.449	30	0.004	0.958	-0.490
13	110	1.113943	2.041393	2.273996	1.24087	0.005	1.454	26	0.004	0.962	-0.492
14	70	1.146128	1.845098	2.114719	1.313609	0.003	1.457	22	0.003	0.965	-0.493
15	64	1.176091	1.80618	2.124232	1.383191	0.003	1.461	19	0.003	0.968	-0.493
16	52	1.20412	1.716003	2.066274	1.449905	0.003	1.463	17	0.002	0.970	-0.493
17	51	1.230449	1.70757	2.101078	1.514005	0.003	1.466	15	0.002	0.972	-0.493
18	40	1.255273	1.60206	2.011022	1.575709	0.002	1.468	13	0.002	0.974	-0.494
19	36	1.278754	1.556303	1.990127	1.635211	0.002	1.469	12	0.002	0.976	-0.494
20	33	1.30103	1.518514	1.975632	1.692679	0.002	1.471	11	0.002	0.977	-0.494

	30321	**166.1939**	**82.21739**	**13664.03**	**27620.42**						

7. Lotka's Law

Table no. 7 Productivity trends of Authors based on Lotka's law

No. of Contribution	**No. of Authors Observed**	**Observed**	**Sn(x)**	**No. of Authors Expected (An)**	**Expected**	**Fo(x)**	**[Fo(x)-Sn(x)]**	
1	19606	0.6466	0.6466	19606	0.5985	0.5985	-0.048141	
2	4529	0.1494	0.2987	4902	0.1496	0.7481	0.449355	
3	1880	0.0620	0.1860	2178	0.0665	0.8146	0.628580	
4	1074	0.0354	0.1417	1225	0.0374	0.8520	0.710310	
5	680	0.0224	0.1121	784	0.0239	0.8759	0.763799	
6	492	0.0162	0.0974	545	0.0166	0.8926	0.795199	
7	337	0.0111	0.0778	400	0.0122	0.9048	0.826970	
8	264	0.0087	0.0697	306	0.0094	0.9141	0.844467	
9	185	0.0061	0.0549	242	0.0074	0.9215	0.866598	
10	156	0.0051	0.0514	196	0.0060	0.9275	0.876046	
11	145	0.0048	0.0526	162	0.0049	0.9324	0.879838	
12	104	0.0034	0.0412	136	0.0042	0.9366	0.895438	
13	110	0.0036	0.0472	116	0.0035	0.9401	0.892977	
14	70	0.0023	0.0323	100	0.0031	0.9432	0.910871	
15	64	0.0021	0.0317	87	0.0027	0.9459	0.914191	
16	52	0.0017	0.0274	77	0.0023	0.9482	0.920750	
17	51	0.0017	0.0286	68	0.0021	0.9503	0.921667	
18	40	0.0013	0.0237	61	0.0018	0.9521	0.928362	
19	36	0.0012	0.0226	54	0.0017	0.9538	0.931207	
20	33	0.0011	0.0218	49	0.0015	0.9553	0.933495	
21	27	0.0009	0.0187	44	0.0014	0.9566	0.937919	
22	27	0.0009	0.0196	41	0.0012	0.9579	0.938265	
23	23	0.0008	0.0174	37	0.0011	0.9590	0.941540	
24	25	0.0008	0.0198	34	0.0010	0.9600	0.940237	
25	18	0.0006	0.0148	31	0.0010	0.9610	0.946142	
26	16	0.0005	0.0137	29	0.0009	0.9619	0.948149	
27	19	0.0006	0.0169	27	0.0008	0.9627	0.945771	
28	12	0.0004	0.0111	25	0.0008	0.9635	0.952372	
29	16	0.0005	0.0153	23	0.0007	0.9642	0.948862	
30	16	0.0005	0.0158	22	0.0007	0.9648	0.948999	

31	10	0.0003	0.0102	20	0.0006	0.9655	0.955228	
32	16	0.0005	0.0169	19	0.0006	0.9660	0.949151	
33	8	0.0003	0.0087	18	0.0005	0.9666	0.957879	
34	12	0.0004	0.0135	17	0.0005	0.9671	0.953648	
35	12	0.0004	0.0139	16	0.0005	0.9676	0.953741	
36	10	0.0003	0.0119	15	0.0005	0.9681	0.956181	
37	8	0.0003	0.0098	14	0.0004	0.9685	0.958729	
39	10	0.0003	0.0129	13	0.0004	0.9689	0.956023	
40	4	0.0001	0.0053	12	0.0004	0.9693	0.963982	
41	4	0.0001	0.0054	12	0.0004	0.9696	0.964206	
42	3	0.0001	0.0042	11	0.0003	0.9700	0.965799	
43	3	0.0001	0.0043	11	0.0003	0.9703	0.966024	
44	5	0.0002	0.0073	10	0.0003	0.9706	0.963331	
45	4	0.0001	0.0059	10	0.0003	0.9709	0.964946	
46	5	0.0002	0.0076	9	0.0003	0.9712	0.963580	
47	2	0.0001	0.0031	9	0.0003	0.9714	0.968336	
48	3	0.0001	0.0047	9	0.0003	0.9717	0.966947	
49	5	0.0002	0.0081	8	0.0002	0.9719	0.963865	
50	4	0.0001	0.0066	8	0.0002	0.9722	0.965589	
51	4	0.0001	0.0067	8	0.0002	0.9724	0.965687	
52	1	0.0000	0.0017	7	0.0002	0.9726	0.970921	
53	4	0.0001	0.0070	7	0.0002	0.9728	0.965857	
54	4	0.0001	0.0071	7	0.0002	0.9731	0.965931	
55	2	0.0001	0.0036	6	0.0002	0.9733	0.969625	
56	2	0.0001	0.0037	6	0.0002	0.9734	0.969749	
57	3	0.0001	0.0056	6	0.0002	0.9736	0.967988	
58	1	0.0000	0.0019	6	0.0002	0.9738	0.971892	
59	1	0.0000	0.0019	6	0.0002	0.9740	0.972031	
60	3	0.0001	0.0059	5	0.0002	0.9741	0.968207	
61	1	0.0000	0.0020	5	0.0002	0.9743	0.972293	
62	3	0.0001	0.0061	5	0.0002	0.9745	0.968326	
63	1	0.0000	0.0021	5	0.0002	0.9746	0.972533	
64	2	0.0001	0.0042	5	0.0001	0.9748	0.970535	
65	2	0.0001	0.0043	5	0.0001	0.9749	0.970611	
66	4	0.0001	0.0087	5	0.0001	0.9750	0.966329	
67	1	0.0000	0.0022	4	0.0001	0.9752	0.972960	
68	4	0.0001	0.0090	4	0.0001	0.9753	0.966328	
71	3	0.0001	0.0070	4	0.0001	0.9754	0.968393	
73	2	0.0001	0.0048	4	0.0001	0.9755	0.970715	

75	1	0.0000	0.0025	3	0.0001	0.9756	0.973163	
76	1	0.0000	0.0025	3	0.0001	0.9757	0.973233	
77	1	0.0000	0.0025	3	0.0001	0.9758	0.973301	
78	1	0.0000	0.0026	3	0.0001	0.9759	0.973367	
79	2	0.0001	0.0052	3	0.0001	0.9760	0.970824	
80	1	0.0000	0.0026	3	0.0001	0.9761	0.973490	
81	1	0.0000	0.0027	3	0.0001	0.9762	0.973548	**Maximum**
83	2	0.0001	0.0055	3	0.0001	0.9763	0.970832	
87	1	0.0000	0.0029	3	0.0001	0.9764	0.973516	
92	3	0.0001	0.0091	2	0.0001	0.9765	0.967354	
93	1	0.0000	0.0031	2	0.0001	0.9765	0.973458	
97	1	0.0000	0.0032	2	0.0001	0.9766	0.973390	
98	1	0.0000	0.0032	2	0.0001	0.9767	0.973419	
100	2	0.0001	0.0066	2	0.0001	0.9767	0.970115	
102	1	0.0000	0.0034	2	0.0001	0.9768	0.973405	
103	1	0.0000	0.0034	2	0.0001	0.9768	0.973428	
104	1	0.0000	0.0034	2	0.0001	0.9769	0.973451	
105	1	0.0000	0.0035	2	0.0001	0.9769	0.973472	
110	1	0.0000	0.0036	2	0.0000	0.9770	0.973356	
115	1	0.0000	0.0038	1	0.0000	0.9770	0.973237	
116	1	0.0000	0.0038	1	0.0000	0.9771	0.973248	
117	1	0.0000	0.0039	1	0.0000	0.9771	0.973259	
119	1	0.0000	0.0039	1	0.0000	0.9772	0.973235	
123	1	0.0000	0.0041	1	0.0000	0.9772	0.973143	
130	1	0.0000	0.0043	1	0.0000	0.9772	0.972948	
131	1	0.0000	0.0043	1	0.0000	0.9773	0.972949	
137	1	0.0000	0.0045	1	0.0000	0.9773	0.972783	
146	1	0.0000	0.0048	1	0.0000	0.9773	0.972515	
181	1	0.0000	0.0060	1	0.0000	0.9773	0.971379	
193	1	0.0000	0.0064	1	0.0000	0.9774	0.970999	
202	1	0.0000	0.0067	0	0.0000	0.9774	0.970717	
211	1	0.0000	0.0070	0	0.0000	0.9774	0.970433	
307	1	0.0000	0.0101	0	0.0000	0.9774	0.967274	

Table nAuthors with a single contribution constitute the largest group, with 19,606 observed authors, which is slightly higher than the 19,606 expected authors. The difference in CDF values ([Fo(x) - Sn(x)]) is negative, indicating that fewer authors than expected have made more than one contribution.

As the number of contributions increases, the observed and expected number of authors decreases. For example, there are 1,880 observed authors with three contributions compared to an expected 2,178 authors. The cumulative difference in CDF values increases with the number of contributions.

For authors with higher contributions (e.g., 10 or more), the observed and expected numbers become very small, showing that both observed and expected distributions tail off. This demonstrates the typical power-law distribution of author productivity described by Lotka's Law.

The cumulative differences [Fo(x) - Sn(x)] show a consistent pattern of deviation between observed and expected values, highlighting the discrepancy between the empirical data and the theoretical model.

The provided table effectively demonstrates the application of Lotka's Law to a dataset of author contributions. While the overall trend follows the expected power-law distribution, specific deviations are notable, particularly for authors with fewer contributions. This analysis is essential for understanding author productivity patterns and can be used to refine bibliometric models and inform research policies.

CONCLUSION

The researchers concludes that corresponding Doubling Time for different year [Dt(P)] gradually increased from 0.983 in 2002 to 9.971 in 2020. It is found that more than four authored publications have the maximum share (62.71%) followed by single authored publications (10.12%). The Pearson Chi-square value 8.78.24 with 80 degrees of freedom is found to be insignificant at 0.05 level of significance (p>0.05). according to the applicability of Lotka's law stated that the D-value 0.974. the above aspect of Lotka's law, the index called Productivity Index (PI) has been applied to identify the level of classification of authors.

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