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Applicability of Lotka's Law in eXtensible Business Reporting Language (XBRL) Studies

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Abstract

The paper aims to present the research trend and to examine the validity of Lotka's law and authorship distribution in the extensible business reporting language (XBRL) studies. Data were retrieved from the Scopus database as of April 2020. A total of 394 documents, with a total of 648 authors have been obtained. The scientific productivity of the articles has been examined using bibliometric analysis and applicability of Lotka's law have been tested using Kolmogorov-Smirnov (K-S) statistics and Chi-square test. This study presents a global picture of the publication trends in XBRL and the authorship of the publications. The findings of the study expose that in the productivity distribution for authors on XBRL studies fit in the Lotka's Law.

Keywords: *Extensible Business Reporting Language, XBRL, bibliometrics analysis, Lotka's law.*

Introduction

XBRL or eXtensible Business Reporting Language is an open eXtensibleMarkup Language (XML) based standard electronic language for electronic communication, especially for business and financial information [1,2]. It is a digital version of business reports that have been widely used to replace the traditional paper-based reports such as PDF or HTML [3]. According to Uyob et al. [4], XBRL is an electronic tool with the acceptable global standard for the electronic financial data to communicate and to be compiled, analysed and shared among the stakeholders. In brief, the use of XBRL is beneficial to the businesses and could provide some impacts in financial reporting.

There are many studies on XBRL have been conducted to understand various aspect of XBRL. For example, De Franco et al. [5] and Dhole et al. [6] examine the impact of XBRL adoption on financial reporting quality. Other studies examine the data quality of financial reporting based on completeness, relevancy, interoperability, transparency, and efficiency [7, 8, 9, 10]. While Uyob et al. [4] and Ahmi and Mohd Nasir [3] present the research output on XBRL based on selected publications on XBRL using bibliometric analysis. Ahmi and Mohd Nasir [3] predicted that, with more studies being conducted, the better understanding of the XBRL could be gained especially in providing better financial reporting quality.

One of the ways in understanding the output of the research, particularly in this area, is to understand the research productivity and the author's productivity. Research productivity can be observed using bibliometric analysis, while the author's productivity can further being tested using Lotka's law. Pritchard [11] describes bibliometrics as "the application of mathematics and statistical methods to books and other media of communication". The bibliometric research also implies a quantitative method that uses statistics to determine text and information and allows an analysis of published documents [12,13].

Lotka's law is deemed as one of the famous laws in bibliometric studies. Lotka [14] defines that the number of authors making n contributions is about $1/n^a$ of those making one contribution, where a is often nearly 2. He further explains that "...the number making n contributions is about $1/n^2$ of those making one, and the proportion of all the authors that make a single contribution is of about 60 per cent" [14]. It means that in a subject or discipline, 60% of the authors produce one publication; 15% ($1/2^2$ * 60) produces two publications; 7% ($1/3^2$ * 60) produces three publications, and so on [15].

Lotka's law has been verified and tested over many research areas to witness the distribution of author and publications [15]. For example, it has been tested in parasitology research [16], library and information science [17], international business [18], physics [19], biomedical science [20], open-

source software development [21], finance [22], and artificial intelligence [23]. From the review in the body of literature pertaining to Lotka's law, none was done on XBRL studies. The recent study on XBRL by Ahmi and Mohd Nasir [3] only focus on the general research productivity using bibliometric analysis while Uyob et al. [4] focus on both bibliometric analysis and systematic review on the impact of XBRL.

Thus, this paper aims to present the current research trends on XBRL and test the applicability of Lotka's law on the productivity of authors in this research area. This paper has three (3) objectives; (1) to analyse the research productivity patterns in XBRL studies, (2) to examine author's productivity from the perspective of Lotka's law, and (3) to apply Kolmogorov-Smirnov (K-S) and Chi-square goodness-of-fit test for the conformity of Lotka's law.

Methods

This paper aims to present the trend of publications using bibliometric analysis in XBRL studies and to test Lotka's law of scientific productivity using the procedure as per Pao [24]. Lotka's law is tested using Kolmogorov-Smirnov goodness-of-fit tests and Chi-square test.

Source and Data Collection

Data were gathered from the Scopus database as of April 2020 for all of the articles that contain the term "XBRL" or "extensible business reporting language" in the title of the article. This query produced a total of 394 documents with a total of 648 number of authors contributed to the publications of the XBRL studies.

Bibliometric Analysis

Based on the data gathered from the Scopus database, a bibliometric analysis will be conducted. According to Ahmi and Mohamad [25], a bibliometric study gains popularity as one of the methods in revealing the trend of studies. The bibliometric analysis also could offer descriptive patterns of publications based on a domain, field, country, period, or amongst all the preceding [26]. Furthermore, a systematic approach in executing a bibliometric analysis could discover more detailed information related to the publications, including the authorship of the paper [27]. This study, however, will focus on the trend of the publications on XBRL as well as the authorship patterns of productivity.

Application of Lotka's Law

Lotka[14] was the pioneer author that initiate and investigate the productivity patterns of authors in chemistry and physics area of studies. His formula, known as Lotka's law is designated as per below

$$x^2 y = C \quad (1)$$

where y is the frequency of authors making x contributions each and C is a constant.

Pao [24], proposed the following procedure should be monitored in order to test the applicability of Lotka's law, i.e. in estimating the value of n, C, and CV.

Estimation of parameter 'n'

The value of n, can be determined either by using the Linear Least Square (LLS) regression method or estimate it using the following equation:

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

where

N is the number of pairs of data considered

X is the logarithm of x

Y is the logarithm of y

Estimation of parameter 'C'

The constant 'C' can be calculated by the following equation:

$$C = \frac{1}{\sum \frac{1}{x^n}} \quad (3)$$

Estimation of parameter 'CV'

To examine the observed frequency pattern of the author's productivity suits the expected frequency pattern, Pao [24] advised applying the non-parametric Kolmogorov-Smirnov (K-S) goodness-of-fit test. Based on the results, the highest deviation between the observed cumulative relative frequency and expected cumulative relative frequencies need to be considered. The value then needs to be compared with the critical value (CV), which can be calculated by the following equation [28]:

$$CV = \frac{1.63}{[\sum y_x + (\sum y_x/10)^{\frac{1}{2}}]^{\frac{1}{2}}} \quad (4)$$

Goodness-of-Fit Tests

For the purpose of this study, the Kolmogorov-Smirnov (K-S) and Chi-square test will be used as a goodness-of-fit tool.

Kolmogorov-Smirnov (K-S) Test

K-S test is conducted by calculating the theoretical $[\sum (yx/\sum yx)]$ and observed $[\sum fe]$ cumulative frequency distribution of authors. The difference at each level of the cumulative frequency distribution is computed $[[\sum (yx/\sum yx)]$- $[\sum fe]]$. The maximum difference $[D_{max}]$ is observed, and further, it is compared with the critical value $[CV]$ calculated using Equation 4. If D_{max} is less than the CV, it is considered to be fit with the Lotka's law.

Chi-Square Test

The Chi-square test is useful in figuring out whether a theoretical distribution such as the Lotka's law fits satisfactorily or not in the observations given where observations fall into certain precise groups within a data set. Based on specific hypotheses or theoretical considerations, if the findings from a sample fall into such defined categories or groups, it would be interesting to understand if the frequencies observed vary significantly from those predicted. If it differs considerably, then the null hypothesis might be failed.

Results

Analysis and Findings

The analysis employed focused on publication trend based on the evolution and growth of published studies on XBRL for 20 years and applicability of Lotka's law on the XBRL publications to test the author's productivity.

Table 1.Growth of publications in XBRL studies.

Year	Research Output	%	Cum. Output	Cum. %	Growth Rate (%)
2001	1	0.25	1	0.25	-
2002	2	0.51	3	0.76	100.00
2003	2	0.51	5	1.27	-
2004	5	1.27	10	2.54	150.00
2005	3	0.76	13	3.30	(40.00)
2006	3	0.76	16	4.06	-
2007	20	5.08	36	9.14	566.67
2008	16	4.06	52	13.20	(20.00)
2009	25	6.35	77	19.54	56.25
2010	36	9.14	113	28.68	44.00

2011	45	11.42	158	40.10	25.00
2012	43	10.91	201	51.02	(4.44)
2013	27	6.85	228	57.87	(37.21)
2014	32	8.12	260	65.99	18.52
2015	26	6.60	286	72.59	(18.75)
2016	20	5.08	306	77.66	(23.08)
2017	31	7.87	337	85.53	55.00
2018	22	5.58	359	91.12	(29.03)
2019	28	7.11	387	98.22	27.27
2020	7	1.78	394	100.00	(75.00)
Total	**394**	**100.00**	**-**	**-**	**-**

Evolution and Growth of Published Studies

Table 1 summarizes the growth of publications in XBRL studies. The earlier research on XBRL is started in 2001. As per Scopus records, the growth of the publication was somewhat slow for the first six years, i.e. from 2001 until 2006. In 2007, a sharp increase was witnessed with a total of 566.67% of growth rate. The trend started to pick up since then, with an average of 29 publications a year. The highest number of publications is observed in 2011, with a total of 45 documents (11.42%). This observation indicates the peak period of the trending on the awareness and implementation of XBRL globally.

Number of Author(s) per Document

Table 2 shows the number of authors per documents. A total of 71 (18.02%) documents were single-authored publications while the remaining documents (which is more than 80% of the total publications on XBRL) were multi-authored publications. The highest number of authors found in XBRL studies are seven (7) in two (2) published article.

Table 2. Number of Author(s) per Document

No. of Author	Total Publications	%	Total No. of Contributions
1	71	18.02	71
2	134	34.01	268
3	125	31.73	375
4	46	11.68	184
5	13	3.30	65
6	3	0.76	18
7	2	0.51	14
Total	**394**	**100.00**	**995**

Productivity Patterns of Authors

There is a total of 648 authors (see Table 3) contributing to the publication of 394 documents on the XBRL studies as gathered from the Scopus database.

Table 3. Productivity patterns of authors and research contributions in XBRL studies.

No. of Articles Produced	No. of Author	% of Author	Total No. of Contributions
1	489	75.46	489
2	85	13.12	170
3	37	5.71	111
4	16	2.47	64
5	4	0.62	20
6	4	0.62	24
7	5	0.77	35

8	3	0.46	24
10	1	0.15	10
11	1	0.15	11
12	2	0.31	24
13	1	0.15	13
Total	**648**	**100.00**	**995**

According to this data set, which is based on the total counting method, 489 authors (75.46%) contributed to one article. The maximum number of articles is 13, and only one author is producing it. It is also evident that the number of authors who contributed more than ten articles is quite small.

Applicability of Lotka's Law in XBRL Studies

To further understand the co-authorship relationship, Lotka's law is applied to the data.

Calculation of the Exponent 'n'

To compute the parameter n data given in Table 4 is used. By substituting the values in Equation 2, the value of n is calculated as:

$$n = \frac{12 * 22.74382 - 20.35494 * 23.73482}{12 * 41.32608 - (20.35494)^2} = \frac{(199.15)}{81.59} = -2.44091$$

Using the value n=2.44091, the value of C can be calculated as follow:

$$C = \frac{1}{1.34444} = 0.74$$

Table 4. Calculation of n-Total counting method.

No.	x	y	X	Y	XY	X^2	x^n	$1/x^n$
1	1	489	-	6.19236	-	-	1.00000	1.00000
2	2	85	0.69315	4.44265	3.07941	0.48045	5.42983	0.18417
3	3	37	1.09861	3.61092	3.96700	1.20695	14.60862	0.06845
4	4	16	1.38629	2.77259	3.84362	1.92181	29.48309	0.03392
5	5	4	1.60944	1.38629	2.23115	2.59029	50.83016	0.01967
6	6	4	1.79176	1.38629	2.48391	3.21040	79.32236	0.01261
7	7	5	1.94591	1.60944	3.13182	3.78657	115.55975	0.00865
8	8	3	2.07944	1.09861	2.28450	4.32408	160.08830	0.00625
9	10	1	2.30259	-	-	5.30190	275.99933	0.00362
10	11	1	2.39790	-	-	5.74990	348.29221	0.00287
11	12	2	2.48491	0.69315	1.72241	6.17476	430.70723	0.00232
12	13	1	2.56495	-	-	6.57897	523.64055	0.00191
	Total	**648**	**20.35494**	**23.19231**	**22.74382**	**41.32608**	**2,034.96143**	**1.34444**

Note: x =number of publications; y = number of authors; X=Log x; Y=Log y

Kolmogorov-Smirnov (K-S) Statistical Test

Coile[29] recommends the K-S statistical test in order to test the applicability of Lotka's law. The K-S test is conducted to examine the conformity of the observed author distribution versus Lotka's distribution [16]. The acquired data are tested against the modified Lotka's law with the exponent n being 2.44091 (see Table 5). The maximum difference value, D_{max}, representing the maximum deviation and being identified as 0.00511. The CV, to centrality level a = 0.01, is calculated as:

$$CV = \frac{1.63}{[995 + (\frac{995}{10})^{1/2}]^{1/2}} = 0.05142$$

While comparing the actual value D_{max}, 0.00511 with critical value 0.05142, it is found that the actual value of D_{max} is lower than the critical value (0.05142) at the 0.01 level of significance. Therefore, the author's productivity data on XBRL fit modified Lotka's law with the value n = 2.44091.

Table 5. K-S test on the observed and expected distribution of authors.

x	y	$yx / \sum yx$	$\sum (yx / \sum yx)$	$1/x^n$	$fe = C(1/x^n)$	$\sum fe$	D_{max}
1	489	0.49146	0.49146	1.00000	0.74000	0.74000	(0.24854)
2	85	0.17085	0.66231	0.18417	0.13628	0.87628	(0.21397)
3	37	0.11156	0.77387	0.06845	0.05066	0.92694	(0.15307)
4	16	0.06432	0.83819	0.03392	0.02510	0.95204	(0.11385)
5	4	0.02010	0.85829	0.01967	0.01456	0.96660	(0.10831)
6	4	0.02412	0.88241	0.01261	0.00933	0.97593	(0.09351)
7	5	0.03518	0.91759	0.00865	0.00640	0.98233	(0.06474)
8	3	0.02412	0.94171	0.00625	0.00462	0.98695	(0.04524)
10	1	0.01005	0.95176	0.00362	0.00268	0.98963	(0.03787)
11	1	0.01106	0.96281	0.00287	0.00212	0.99176	(0.02894)
12	2	0.02412	0.98693	0.00232	0.00172	0.99348	(0.00654)
13	1	0.01307	1.00000	0.00191	0.00141	0.99489	**0.00511**

n =2.44091; c =0.74; D_{max}=0.00511; x = Frequency of papers; yx =Relative frequency of authors with X research papers; $yx/\sum yx$ = Fraction of observed number of authors; $\sum (yx/\sum yx)$= Cumulative fraction of observed number of authors; $fe = C(1/x^n)$= Fraction of expected number of authors; $\sum fe$ = Cumulative of the theoretical value of authors; D_{max}= Difference between the observed and expected cumulative value of authors.

Chi-Square Test

The analysis of the author productivity on XBRL is further being expanded as per Table 6. This table was prepared to conduct the Chi-square test.

Table 6. Chi-square test on XBRL studies for applicability of Lotka's Law.

No. of Articles	Observed No. of Publications (Fi)	Expected No. of Publications (Pi)	Fi-Pi	$(Fi-Pi)^2$	$X^2 = (Fi-Pi)^2/Pi$
1	489	489	0	0.00000	0.00000
2	85	90	-5	25.58343	0.28408
3	37	33	4	12.43694	0.37155
4	16	17	-1	0.34313	0.02069
5	4	10	-6	31.58746	3.28343
6	4	6	-2	4.68600	0.76013
7	5	4	1	0.59047	0.13954
8	3	3	0	0.00298	0.00097
10	1	2	-1	0.59559	0.33616
11	1	1	0	0.16321	0.11625
12	2	1	1	0.74763	0.65851
13	1	1	0	0.00438	0.00469
Total	**648**	**657**	**-9**	**76.74123**	**5.97599**

The calculated value of chi-square obtained is 5.97599, and the critical value at 5% level of significance is 21.026. On comparing, it is found that the value of Chi-square is less than the critical value of chi-square. The statistical tests showed the Lotka's law fit the data of the author's productivity on XBRL studies.

Conclusion

This study presents a universal view of the research trend, distribution of papers as single-author papers and multiple-author papers and applicability of Lotka's law in XBRL studies. While the adoption and implementation of XBRL are varied among countries, the number of studies of XBRL still unpredictable. However, there are still quite a number of researchers focuses on this study year by year. This study also had tested the applicability of Lotka's law in the author's productivity. Lotka's law was employed on the data to predict and comprehend the author's contributions. The present analysis reveals that Lotka's law is applicable to XBRL studies. Both K-S and Chi-square have confirmed the applicability of Lotka's law and found that this law fit the author distribution of XBRL studies.

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