Lotka's Law and GBV literature 2009-2018: a case study of South Africa

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Abstract

South Africa is noted for high numbers of gender-based violence (GBV), hence an informetrics analysis was conducted on her GBV research output to fit Lotka's law of scientific productivity over a ten-year window, 2009-2018. Data was harvested from the EBSCO Discovery Service Database. The result c = 80% and á =2.78; conceded a greater number of GBV scientists to single contributors even though these values exceeded Lotka's benchmark of c = 60% and á= 2. These marked differences notwithstanding, author's productivity of GBV literature concurs with Lotka's law, in that a large number of researchers contributed one publication each on GBV; while less than 1% of authors contributed 11 articles on average. This could be due to the fact that GBV, being a public health problem, intersects many areas of subject specialty within and outside the medical profession, which could have prompted multi-disciplinary scientific investigations. In addition, a dearth of GBV research was clearly seen, as fewer than three publications in a month were recorded. The implication is that if Gender-based violence (GBV), is not giving adequate research attention, it could jeopardize Government's effort at curtailing the spread of HIV/AIDS because of its many pathways.

Keywords: Informetrics, Lotka's law, Gender-based violence (GBV), South Africa.

Introduction

The *Dictionary of Bibliometrics* defines Law as "Eponymic statements in Bibliometrics, Informetrics, and Scientometrics" (Diodato 1994:99). The laws are explanations or

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premises of patterns that are clearly seen in the publication and use of information. Three well noted laws are: Lotka's law of scientific productivity, Bradford's law of scattering of journals, and Zipf's law of word occurrence. This set of laws is intended to enhance the status of informetrics from a procedure to a scientific theory different from the conventional laws of the physical sciences (Egghe and Rousseau, 1990) . In 1926, Alfred Lotka, an American statistician, came up with a hypothesis which he derived from a summary of two samples drawn from the Chemical Abstracts 1907-1916 listed in Auerbach's Geschichtstafeln der Physik. Lotka used the size-frequency approach to analyse the publications of the chemists and physicists according to their distributions, and concluded that the number of persons making n contributions is about $1/n^2$ of those making one, and the proportion of all contributors that make a single contribution is about 60%. He termed this outcome the "inverse square law of scientific productivity" because there is an opposing nexus between the quantities of publications and the number of authors turning out such documents (Coile 1978; Nicholls 1989; Potter 1981). According to Potter (1981), Lotka's article received its first citation in 1941, while his distribution was adjudged "Lotka's law" in 1949. However, the test of the fittingness of Lotka's law materialised in 1973. Since then, the application of Lotka's law to various scientific disciplines has been on the increase, irrespective of divergent shortcomings of the original formulation of the law.

Gender-based violence

Gender-based violence (GBV) is a widely known public health, human rights and human continuity issue that has attracted a global outcry in many places. It happens across the world, irrespective of culture, race, age, and social class (Mcquaid & Mcquaid, 2017; Naciri, 2018). Lange & Young, (2019) describe it as a staggering normalised global phenomenon that has defied education, to unduly harm women and girls especially native women, women of colour, those markedly disabled, gay, and bisexual, transgendered individuals, and women who are poor. According to the authors, gender-based violence is historically embedded in the heart constructs of patriarchy, and commonly reinforced across cultural, economic, religious, educational and political spheres.

Consequently, men have not only being identified as lifelong perpetrators of violence, but also it is claimed that customs and culture shield them from legal penalties and prosecution; while women and girls, on the other hand, are victims of the various forms of gender-based violence and harmful practices, such as gender inequality, child marriage, and female genital mutilation (Casta, Garcý, Herna, Muelas, & Santamaria, 2018; García-Moreno *et al*. 2015; Hillis, Mercy, Amobi, & Kress, 2016, UN Women, n.d.)). However, there is evidence that men do experience gender-based violence too, though occurrence is of incomparable magnitude with resultant risks on the former because it is the common cause of injury to women (Bueno-Hansen 2018; Maquibar *et al*. 2018; Naciri 2018).

South Africa has the highest estimated number of occurrences of GBV in the world. According to Statistics South Africa (Stats SA) in the Crime against women in South Africa Report (2018), an estimated 138 per 100 000 women were raped in 2016/17, being the highest rate in the world (DHET Policy Framework on GBV 2019). Three women get killed by an intimate partner every day (Snodgrass, 2017). This is nearly five times above the global average of 2.6 per 100 000. Evidenced Report revealed that 39 per cent of women have suffered one form of SGBV in their lifetime. Even members of the community of lesbian, gay, bisexual, transgender, queer and intersex (LGBTQI) are violated as well. Mills et al. (2015) named the cause of the various forms of violence as the socio-economic inequalities that pervaded the long era of apartheid in the country. The ten-year time frame, 2009-2018, was chosen on the grounds that publications during such periods are relatively recent.

Literature review

Given the fact that Lotka's study was supposedly a mere hypothesis model based on an inverse square law which was not grounded on an empirical law (Nicholls 1989); a number of controversies have arisen in attempts to confirm the validity of Lotka’s law empirically. Some of the debates on Lotka’s law are largely on issues pertaining to: population of authors; methods of data collection; calculation of the two constants (*á and c*); and problems with the validity of the observed data to the theoretical distribution. These methodological inaccuracies have implications on overall

assessment of scientists' in that it can underestimate their research productivity. For instance, the issue of population of authors is a common controversy. Whereas, co-authorship is an acceptable measure of scientific productivity, it was ignored in Lotka's initial hypothesis. Lotka considered only the lead authors (Potter 1981:22).

Early works of scholars such as Chen and Leimkuhler (1986); Pao (1985; 1986); and Potter (1981) acknowledged some methodological deficiency which made the application of Lotka's law more controversial. Pao (1986), stated that bestowing "full productivity" of authorship on lead authors alone is a disservice to the remaining authors. Therefore, the complete count, that is, ascribing equal credit to all authors, is considered ideal because treating co-authors fractionally would markedly downplay the productivity of a substantial number of authors (Ahmed and Rahman 2009). Nicholls (1989) suggested different views on how best to resolve these issues. For instance, Nicholls (1986), stressed that a robust testing methodology is an essential prerequisite to the validation and generalisation of Lotka's law.

Potter (1981:37), on the other hand, stressed that the use of large bibliographic databases could inject some standards into the methods of data collection. Yablonsky (1980:4) claims that Lotka's scientific productivity can be determined through direct statistical counting of frequency and ranking approach; Pao (1985), maintains the need to test the conformity of the observed distribution vis-à-vis the theoretical distribution function with a suitable statistical test of goodness-of-fit, at a specified level of significance. Gupta (1987:45) concluded that applications of Lotka's law should only be treated as estimates of general and theoretical productivity rather than precise statistical distribution.

Some of the recent studies that have confirmed Lotka's law include: Shenton (2017), who applied Lotka's law to investigate the authorship of the original "Doctor Who library" a novelisation series from a small number of writers, while many authors had no more than one contribution each. Nonetheless, there was no evidence that a statistical test for goodness of fit was performed todetermine the fitness of Lotka's law to the objects of research. Tsay and Lai (2018), conducted a Scientometrics study on the literature of Heat transfer from 1900 to 2017 based on the 120,628 data harvested

from Web of Science. The findings followed Lotka's law, in that 61.3%, (79,655) of 130,037 authors contributed one article only, while 15.9% of the authors had two articles each to their credit; authors of three articles contributed 7.0%, and four articles 4.0%. The outcome of the least square method showed the value of the exponent á in a slope of -2.15, which was also near to Lotkas' exponent á value of -2. However, contrary to the suggestion that applicability of Lotka's law to a set of data must be subjected to a statistical test, these values were not subjected to any test-of-goodness to determine the conformity of the data.

López-Muñoz *et al*. (2018) after applying Lotka's law to the analysis of scientific production on second generation anti-psychotic (SGA) drugs in Malaysia, found that the authorship distribution was in accordance with Lotka's law. The authors discovered that a huge number of authors have few publications while a high number of publications clustered around small numbers of researchers.

Similarly, there are several fields of studies in which Lotka's law of distribution did not hold sway, which proves that some scientific disciplines do not tally with Lotka's pattern of authorship distribution. For instance, studies such as that by Ahmed & Rahman (2009), in the field of nutrition research, Bangladesh; Sadik (2018) on research productivity of Annamalai, a higher education institution in India; Merediz-Solá and Bariviera (2019) concluded that authorship in Bitcoin's scientific production is widely and evenly spread. Nunes-silva *et al*.'s (2019) result on the other hand did not conform to the productivity standards suggested by Lotka. Moreover, Savanur (2013) applied Lotka's law in cloud computing research and tested his findings through the three methods, namely: Sen's Method, Pao's Method, and Maximum Likelihood Method using Kolmogorov-Smirnov (KS) Test as a test-of –goodness to measure its validity. He found that the values of exponent (á) and constant (C) derived from the three methods contradicted Lotka's Law of pattern of authorship productivity in the field of Cloud computing research.

Research purpose

To examine the validity of Lotka's law, on GBV literature using “full productivity" of authorship, and undertake Two-tailed test- of- goodness to confirm the results. Arising from the above aim, the study shall provide answers to the following questions:

1. Does Lotka’s “inverse square law” of scientific productivity hold in the literature of GBV?

2. Does using 2 tailed T-test as goodness-of-fit test confirm Lotka’s law in GBV literature?

Methodology

EBSCO Discovery Service (EDS) was preferred for this study because its services offer a wide range of information from a pool of databases. Only articles in peer reviewed journals were considered as they are the most acceptable and easily measurable source of research (Alcaide and Gorraiz 2018).

This study is based on bibliometrics, therefore terms such as ‘gender-based violence’ OR ‘gender violence’ OR ‘gender inequality’ OR ‘women abuse’ OR ‘women trafficking’ OR ‘domestic violence’, OR ‘intimate partner violence’, OR ‘sexual violence’, OR ‘child abuse’, OR ‘child trafficking’, OR ‘homosexuals’ OR ‘same sex’, OR lesbians OR gay. The LGBTQ were included in the search because they often get abused on the basis of their gender identity. All these terms were searched along with …. ‘AND South Africa’ from seven databases housed in EBSCO Discovery Service (EDS). The databases were: Business economics, Communication/media, Education, Health Sciences, History, and Life Sciences and Psychology/Sociology. The study employed ENDNote and Microsoft Excel Spreadsheets to capture, clean up and analyse data. EndNote was used to export data from EBSCO to get full view of the bibliographic details of the data for easy counting of the number of publications and the authors. SPSS and Microsoft Excel Spreadsheet, on the other hand, were used to obtain calculations of various values. A total of 300 journal articles were found useful for the study.

Findings and discussions

This section discusses the findings based on the objectives of the study using publications count to determine productivity pattern of researchers of GBV in South Africa.

Table 1 Distribution of GBV research publication

Year	No	%
2009	29	9.67
2010	29	9.67
2011	32	10.66
2012	30	10.00
2013	27	9.00
2014	35	11.67
2015	34	11.33
2016	34	11.33
2017	26	8.67
2018	24	8.00
Total no. of authors	300	100

Table 1 above shows the trend of GBV research publications for the period under analysis. A total of 300 journal articles were appraised, published in the period from 2009 to 2018. South Africa seemed to have paid much attention to GBV in 2014, 2015 and 2016 as the total publications for the three consecutive years amounted to 34.3% of the total publications. This unprecedented publication output may be attributed to the mounting global outcry against GBV which was also embraced in Africa. The prevailing uproar against GBV at the time could have spurred enquiries. For instance, in 2013, World Health Organisation (WHO) did a multi-country study on global and regional estimates of violence against women; the research revealed stunning findings which could have elicited further research.

Table 2 Distribution of authors' contributions

Number of Contributions (x)	No of authors (y)	% of Authors
1	488	79.09
2	71	11.51
3	24	3.89
4	10	1.62
5	13	2.11
6	6	0.97
8	3	0.49

9	1	0.16
22	1	0.16
Total	617	100

Table 2 shows Lotka's distribution in its generalised form. The entire 617 authors were considered and ascribed full authorship based on full-count method. A look at the distribution of articles in Table 2 shows that about 80% of GBV researchers contributed one journal article, while about 12% contributed two articles each, and about 4% contributed three articles each; while a total number of 5 authors (less than 1%) contributed on average 11 items each. This result did in fact reflect Lotka's original results closely.

Sen's method

Many authors have attempted to apply a variety of methods to verify the applicability of Lotka's law in various fields of research. But the most notable methods are: Least Square Method along with Kolmogorov-Smirnov goodness-of-fit; Pao (1986); Maximum Likelihood (ML) method through a computer program named LOTKA (Ahmed and Rahman 2009) and Sen's method in conjunction with t-test for goodness-of-fit. However, this study follows Sen's method to examine the conformity of Lotka's law on the research productivity of GBV in South Africa, and thereafter validated its applicability through t-test analysis. The Two-tailed test was preferred because it detects the strength of relationship between the means of the observed and expected values (Roy, 2019).

Sen (2010), wrote a short communication in *Annals of Library and Information Studies*, in which he described, and demonstrated through simple equation method how the parameter values of c and á could be determined with less tabular columns compared to Pao's Least Squares Method (LSM).

Sen's method is thus represented

$$x^{á} y = c \qquad \text{[Eqn. 1]}$$

Where, Y is the number of authors credited with X (1, 2, 3, 4, 5, 6, 8, 9……) papers

C is the number of authors contributing one paper.

From the above equation

X=1; Y=488

1^{α}*488=C

To determine the value of á apply the data of the second row

2^{α}*71=488

Divide both sides by 71

$\frac{2^{\alpha}}{71}*\frac{71}{71} = \frac{488}{71}$

$2^{\alpha} = \frac{488}{71}$

2^{α}=6.87

Take the log of both sides

á*log2 = log 6.87

á*.3010 = 0.837

$á = \frac{0.837}{.3010}$

á= 2.78

Given the values of exponential á =2.78 and c= 488, we calculate the number of the expected authors with these values.

E.g. Authors contributing 2 papers: $Y = \frac{488}{2^{\wedge}2.78}$

$= \frac{488}{6.87}$

= 71.03

Authors contributing 3 papers 488

3^2.78

= 488

21.20

= 23.02

Table 3: Verification of Lotka' s law using Sen's method

Papers (x)	No of authors (y) Observed	% of observed Authors	No of authors (y) Expected with α 2.78
1	488	79.09	488
2	71	11.51	71
3	24	3.89	23
4	10	1.62	10
5	13	2.11	6
6	6	0.97	3
8	3	0.49	2
9	1	0.16	1
22	1	0.16	0.1
617	100	604.1	100

From the foregoing, the calculated values for observed authors were found to be very close to Lotka's generalised law. Whereas Lotka had forecast that, in any given field, 60% of all the authors will have one publication each, 15% will contribute 2 publications, while 7% will contribute 3 publications, etc. this study on the other hand discovered that GBV scientific productivity did not exactly conform to the statistical proportions stated by Lotka's Law. However, there is a reflection of the general patterns of the Law in this outcome. For instance, almost 80% of all the authors had one GBV publication each; almost 12% had 2 publications; 4% contributed 3 publications each.

Table 4: Result of the T-test analysis

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
NoAuthors	Equal variances assumed	.000	.991	.019	16	.985	1.43333	75.00868	-157.57795	160.44462
	Equal variances not assumed			.019	16.000	.985	1.43333	75.00868	-157.57814	160.44481

To further ascertain the credibility of the findings, a Two-tailed statistical analysis was carried out on the data set. Table 4 above confirmed that for a two-tailed test, there is no statistically significant difference between the observed number of GBV authors and the expected number of GBV authors in South Africa. Thus the above-mentioned results signify that the scientific productivity of GBV literature conforms to Lotka's Inverse Square Law with the exponent á=2.78 and C= 488 respectively.

Conclusion and recommendations

This study explores the productivity of researchers in the field of GBV, with a view to verifying the application of Lotka's law of scientific productivity. The study harvested 300 publications on GBV from EBSCO Discovery Service (EDS) published between 2009 and 2018 in South Africa. Findings reveal that the GBV scientific output adheres to Lotka's law of productivity distribution both in generalised form and in inverse square law using "full productivity" of authorship; using Sen's method, this study found n = 2.78 and c =488. When the data set was further subjected to Two-tailed T-test with 16 Degree of freedom (df), the result for equality of means (p=0.985) still reveals that there is no statistically significant difference between the observed and the expected number of authors. Hence, Lotka's law holds in the field of GBV and its scientific literature.

This result concurs with a number of studies whose findings correlate positively with Lotka's law of scientific productivity. For instance, Roy (2019), replicated Sen's method with a two-tailed goodness-of-fit tests on the contributions of Indian researchers in the field of Biological Science over a period of 45 years. He discovered that the Biological science literature followed Lotka's law of scientific productivity with C and á parameters values of 714 and 1.884 respectively.

Likewise in the field of dentistry, Batcha (2018), showed that the authorship frequency distribution follows Lotka's Inverse Law accurately with the exponent á=2, and further discovered that with K-S test of goodness, parameters á and C 2.49 and 0.7433 for dentistry literature, Lotka's law fits the global dentistry research output. Also, the findings were in tandem with Asubiaro (2018), who confirmed that the distribution of publications by biomedical authors is highly collaborative because medical research often require field and laboratory investigations, therefore, a high rate of co-authorship is inevitable (Rotich and Onyancha 2017). Moreover, GBV being a public health issue with physical, reproductive, and mental problems for human lives, especially women and children require more detailed professionalism through extensive supervision, consultations, cross-examination of decisions and actions which often result in publications (Nwagwu 2006).

However, this finding contradicts Adigwe's (2016) study which reported that productivity distribution for the all-authors and first-authors categories on the subject of HIV/AIDS differs from the distribution of Lotka's inverse square law. Studies have not only reported HIV/AIDS as the most researched topic, but have also confirmed its direct and indirect pathways with different forms of GBV (Krusi *et al*. 2018; Pouris and Ho 2014; Rotich and Onyancha 2017). An average of 30 GBV journal articles per annum over a ten-year window as recorded in this study is a clear indication of a dearth of researchers on GBV. Thus, South Africa's efforts at curbing the spread of HIV/AIDS could be jeopardised if adequate attention is not giving to GBV research. Therefore, the country needs to promote more research into GBV to solve the menace.

This study is aware that other databases could have housed more GBV publications than were found in EDS. Therefore, it is recommended that Lotka's Law be tested on GBV publications from South Africa through other databases.

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