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Growth of journals, articles and authors in malaria research

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ABSTRACT

In the present study we have tried to trace the growth of malaria research at Global Level and the distribution of articles in various journals for the period 1955–2005. The data have been extracted from a database, which has been developed in-house from MEDLINE, SCI, TDB, Ovid Heath Information and Indian Science Abstracts. Study indicates that the exponential model fits the data on journals, articles and authors. The R^2 value for the trend for journals, articles, and authors are 0.9502, 0.9475, and 0.9651, respectively. The growth rates for journals, articles and authors are 5.31%, 7.38%, and 10.06%, respectively. The linear multiple regression equation that Articles = −39.2771 + 3.61719*journals + 0.085882*Authors (R^2 = 99.16%) is most meaningful and it may be used to estimate the articles for given numbers of journals and authors.

1. Introduction

The number of scientific journals including abstracting periodicals is simple indicators of scientific growth. Price (1963) in 1963 argued that scientific literature grows exponentially and computed the growth rate as 5% over the past two centuries. He further observed that literature doubles approximately once in 15 years. Neelameghan (1963) analyzed the documents on the history of medicine in India for the period 1954–1961, during which period Indian contribution was 65% and foreign was 30%. He studied the growth of Indian medical societies and medical periodicals between 1780 and 1920. He also studied the coverage of Indian medical literature in Index Medicus and Experta Medica and it was found that they respectively covered only 38% and 13.5% of the Indian literature. Since then a number of articles have been published on this topic, particularly on the growth of literature in different subjects and on various growth models. The number and the growth characteristics (of articles, journals, scientists, discoveries, etc.) have been matters of some debate for a considerable time. Naranan (1970) has shown that a frequency distribution ($J(p)$) of the number of journals with p article is of the form $J(p) \propto p^{-\alpha}$. With $\alpha = 2$, this model reproduces the salient features of Bradford's law. He has developed his model on the assumption that journals increase exponentially and also articles in each journal increases exponentially. Egghe (2005) has shown that growth rates of sources usually are different from growth rates of items. Further he has shown that linear three-dimensional informetrics is capable to model disproportionate growth.

Moravcsik (1984) in 1984 pointed out that "an overwhelming fraction of work in the science of science and in fact in many areas of inquiry has been carried out in an implicitly or explicitly one-dimensional framework and one-dimensional methodology." He defined the one-dimensional model as "the one in which events, factors, causes and effects can be arranged in a linear chain ordered either chronologically or in a logical sequence." Classical bibliometric studies (Bradford's study,

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Lotka's law, Zipf's law) are examples of two-dimensional studies. In general, good examples of two-dimensional studies are those which discuss source-item relation. Egghe (2003) gives many examples of one, two and three-dimensional informetrics. Egghe (2003) also discussed a theory to solve a part of three-dimensional informetrics in which two information production processes (IPPs) determine a third one. In two or three-dimensional informetrics, relations among the variables are studied either using linear or non-linear models–linear regression can generally be applied in such cases.

In this paper an attempt has been made to study a three variable linear model consisting of authors, articles and journals (a three-dimensional approach), particularly to predict the values of a variable (generally known as dependent variable) based on the other two variables.

2. Objectives of the study

In the present study, we have tried to trace the growth of malaria research at global level and the distribution of articles in various journals for the period 1955–2005. This paper probably is the first to provide a consolidated and comprehensive analysis of growth of papers, journals and authors in the field of malaria around the world. In particular, the objectives of this research are to study and understand:

- Growth of literature in malaria research with respect to authors, articles and journals.
- Relation among the authors, articles and journals—by applying multiple regression analysis to identify a most relevant linear regression model, particularly for the purpose of prediction.
- Influence of growth of literature on scattering.

3. Related works

A few selected scientometric papers in which the multiple regression analysis is applied are discussed. Also quantitative analyses of literature in the area of malaria and related topics are discussed.

Peters and van Raan (1994) in their article "on determinants of citation scores", investigated a broad spectrum of scientific papers. Using multiple regression analysis, the authors have found that the factor 'top authors' contributes the largest number of citations. The other important factors, according to the authors are number of references, languages, journal category and journal influence. Cohen (1981) in an article on "publication rate as a function of laboratory size in three bio-medical research institutions" observed that "there is no indication of a single laboratory size at which the number of publications per scientists is maximal or minimum." Based on regression analysis, the author attempted to identify a relation between the number of scientists in a laboratory and the number of their scientific publications in a year. In a bibliometric analysis of global knowledge management research, Gu (2004) applied regression analysis techniques. Gu (2004) has observed a linear relation between citation frequency of articles and impact factor of journal; the author has further observed that R&D expenditure was actually not proportional to research productivity or citation counts.

Coleman (1994) in the article "disciplinary variables that affect the shape of Bradford's bibliography", applied multiple regression analysis on the sixteen bibliographies with the curvature of Bradford's Bibliography on the predicted variable and with other six properties of the source bibliography serving as predictors. The six properties of the source bibliography are range (in years) of the bibliography, total publications, total journals, density of the bibliography, whether the disciplinary source is technical or not and whether the bibliography is comprehensive. He has suggested a multiple regression equation involving these six variables to predict the "curvature."

Walters (2006) in a study on predicting citations to articles published in twelve issues of psychology journals, based on multiple regression analysis argued that author impact may be a more powerful predictor of citations received by a journal article than the periodical in which the article appears. Rajeshwari (1983) attempted to analyze the science and technology manpower in relation to economic development based on regression analysis. She has observed that the number of S & T personnel depends on a proportionately very large increase in GNP, industrial output, and R&D expenditure. All the regression seems to be fairly good fits. A number of multiple regression analyses have indicated in quantitative terms the extent of growth expected in Gross National Product (GNP), industrial output and R&D expenditure to absorb the available supply of S & T personnel.

Thus, regression analysis techniques have been applied in scientometrics in different context particularly to predict the data with respect to the dependent variables. Most of these applications were centered on two-dimensional studies. Only a few studies discussed three-dimensional informetrics. Egghe (2005) has shown that three-dimensional informetrics is capable of modeling disproportionate growth. There are many scientometric studies which have reported quantitative analysis of literature in malaria research. A few selected papers are discussed below.

Garg, Dutt, and Kumar (2006) in their study on "a preliminary scientometrics investigation of malaria research" analyzed 2275 papers on malaria research published in journals and indexed by Commonwealth Agricultural Bureaux International (CABI) CD-ROM incorporating Tropical Diseases Bulletin (TDB), and PubMed Medline (web edition) in 1990 and 2000. Their study indicated that:

- The Science Citation Index (SCI) covered only about 68% of the output indexed by CAB.
- In PubMed Medline (web edition), malaria research output is highly scattered both in terms of the sub-fields of the journals as well as the publishing country of the journals.
- The publication activity in Brazil increased significantly during 2000 as compared to 1990.
- Most of the prolific institutions are located in the developed countries, particularly in the UK and the USA.
- 'Parasite biology' constitutes the highest output (37%) followed by 'epidemiology'(19%) and 'drug resistance and antimalarials' (16%).
- USA and Australia emphasized different aspects of 'parasite biology'.
- China and Brazil emphasized different facets of 'epidemiology'.
- Nigeria and Thailand paid more attention to 'complicated malaria and its adverse effects' and 'drug resistance and anti-malarials'.

Lewison and Srivastava (2008) pointed out that Malaria is estimated to cause about 1.6% of the 57 million deaths occurring annually and 2.3% of the disease burden. However, malaria research accounts for only about 0.4% of world bio-medical research. According to the authors, this percentage is barely changing. Apart from this fact, they observed that most of the research is taking place in Europe and North America, which are hardly affected by the disease. Most of the affected area on the other hand is sub-Saharan Africa. Rodriguez, Fonseca, and Chaimovich (2000) in their article on 'Mapping Cancer, Cardiovascular and Malaria Research in Brazil' pointed out that there is a decrease in the output of malaria research; it is about 0.89%; further, they mentioned that malaria research (about 468 articles) is more evenly distributed across the country, following the pattern of the endemic distribution of disease. Fialho and Srinivas (2004) studied malaria-related research output in two countries, Brazil and India, countries with most advanced science and pharmaceutical capabilities in the developing world. They assessed local relevance of science and also its integration with international research by looking at almost 60 years of scientific publications on malaria between 1945 and 2003. MacLean, Davies, Lewison, and Anderson (1997) studied international funding for research in malaria and analyzed malaria publications output for 1984, 1989 and 1994 and its impact using citations for different countries and funding agencies. The results of their study are based on PRISM Report No. 7 carried out by Anderson, MacLean, and Davies (1996). In another study, Lewison, Lipworth, and De Francisco (2002) used a bibliometric approach to estimate research funding for malaria for the years 1996–2000.

All these studies have used the Science Citation Index (SCI) on CD-ROM, published by the Institute for Scientific Information (now Thomson Reuters) as the source of data. The SCI does not index a large number of journals published from developing countries such as Brazil, China and India. A quantitative analysis (based on SCI data) of research output of malaria research is therefore incomplete.

4. Data collection

In view of the importance of malaria research in the field of human health and well being it is important to map the research activities being carried out by researchers around the world. Since research publications are one of the major outputs of any research activity which can be quantified, it may reveal the trend of work being carried out in this area. For this purpose, we need a searchable consolidated database, but there is no exclusive comprehensive global database on malaria publications and for Indian efforts also in the field of malaria, there is no single source available. The literature is being generated by scientists in India is dispersed in various documents, making mapping research output difficult. A comprehensive database therefore has been developed with bibliographical details of all the research papers published in any scholarly journal around the world. It is hoped that the database will facilitate a quick access to all the malaria-related research papers appearing in journals during the last 50 years. The required bibliographic data have been captured from Science Citation Index (Expanded-online version, Web of Science 1955–2005), MEDLINE (1955–2005), Ovid (Global Health) (1972–2005), Tropical Disease Bulletin (1955–2005) and Indian Science Abstracts (1965–2005). The data have been completed manually, wherever needed. Some of the left out journals which were not covered by any of these services but were important as identified by the peer group in the field were also physically consulted, Malaria research output is highly scattered (in journals, patents, published in several countries, in different languages, etc.) The data from hard copies were collected on pre-designed formatted input sheets. The fields were decided in consultation with subject specialist of the area as well as experts from information science. Each record was provided with appropriate Keywords: and Institutional affiliation of the author (wherever available).

Once the basic data for other than Indian research papers, were captured from the digital sources, it was converted into searchable database format (compatible with the database for the data from hard copy) through a specifically developed conversion program for the purpose. Duplicate entries from different secondary services were removed by systematically screening the records, by special utility program for the purpose. Finally, the database of Journal Research Papers on Malaria was developed; it is called MALPUB[1]. The MALPUB is global in coverage and includes Indian malaria research during 50 years from 1955 to 2005. The distribution of the data in different sources is as follows:

[1] The readers may contact the 2nd author for more details and for its availability.

Source	Period	Number of papers
Web of Science (WOS)	1955–2005	42,713
MEDLINE	1955–2005	51,563
TDB	1955–2005	30,000
Ovid	1972–2005	38,138
ISA	1965–2005	5,000

After removing the duplicate records, there are 122,110 records in the database (MALPUB) for the period 1955–2005. That is, 3996 publications during 1956–1965, 9667 publications during 1966–1975, 17,923 publications during 1976–1985, 32,897 publications during 1986–1995 and 57,627 publications during 1996–2005. All these papers appeared in a total of 502 (1955–1965), 953 (1966–1975), 1339 (1976–1985), 2070 (1986–1995) and 3072 (1996–2005) journals. From these data sets, data on number of papers, authors and journals were computed for different years and are given in Tables 1 and 2.

5. Growth of journals, articles and authors

Table 1 gives the number of journals, articles and authors in the area of malaria research. It suggests that all the three variables (journals, articles, and authors), increase exponentially. The number of articles has increased from 3996 (1955–1965) to 57,627 (1996–2005) (more than fourteen times). Also the number of journals has been increased 502 (1955–1965) to 3072 (1996–2005) (about six times). Figs. 1–3 clearly indicate that the exponential model fits the empirical data. The R^2 value for the trend for journals, articles, and authors are 0.9502, 0.9475, and 0.9651, respectively. Under the assumption that the data confirms to exponential model, the growth rates have been computed; the growth rates of the journals, articles and authors are 5.31%, 7.38%, and 10.06%, respectively. However, the growth rates of journals, articles and articles per journals, for the grouped data as given in Table 2 (row 4), are 4.45%, 6.73%, 2.12%, respectively. The R^2 value for the trend (for grouped data) for journals, articles and articles per journals are 0.9906, 0.9933, and 0.9889. It thus confirms that journals, articles, authors and articles per journals increase exponentially.

5.1. Relation among the three variables—journals, articles and authors

A multiple regression analysis was carried out to study and understand the relation among the three variables. With the three variables, we have the following three possible linear regression equations; these equations were fitted to the

Table 1
Number of Journals, Articles and Authors in malaria research.

Year	# of Jour.	# of Articles	# of Auth.	Year	# of Jour	# of Articles	# of Auth.	Year	# of Jour.	# of Articles	# of Auth.
1955	127	343	619	1972	312	1136	2,663	1989	490	2893	11,055
1956	109	297	495	1973	320	1070	2,635	1990	527	3183	12,749
1957	92	267	428	1974	332	1048	2,491	1991	588	3827	15,461
1958	93	198	347	1975	302	1138	3,211	1992	586	3735	14,999
1959	89	200	325	1976	275	1291	3,675	1993	579	3105	12,687
1960	76	179	308	1977	295	1466	4,176	1994	621	3860	15,928
1961	92	244	446	1978	310	1477	4,209	1995	704	4309	18,787
1962	78	215	386	1979	349	1730	5,126	1996	734	4343	18,571
1963	104	290	551	1980	344	1579	4,706	1997	793	4710	20,277
1964	158	543	990	1981	349	1743	5,467	1998	782	4426	19,044
1965	163	546	1077	1982	397	2108	6,635	1999	859	5248	23,038
1966	160	760	1585	1983	398	2134	6,846	2000	855	5366	24,180
1967	187	755	1673	1984	417	2251	7,639	2001	901	5609	26,006
1968	201	866	1758	1985	429	2005	6,741	2002	1079	6139	29,572
1969	210	1031	2296	1986	451	2408	9,138	2003	1170	6824	35,486
1970	278	979	2090	1987	437	2706	10,539	2004	1201	7380	38,606
1971	286	1014	2249	1988	492	2898	11,718	2005	1273	7542	39,650

Table 2
Number of Journals and Articles in Malaria research for the period 1955–2005[a].

	55–65	66–75	76–85	86–95	96–05
# of articles in zone 1 (# of journals).	1348 (8) [168.5]	3212 (8) [401.5]	6082 (12) [506.8]	11,028 (15) [735.2]	19,140 (18) [1096.7]
# of articles in zone 2(# of journals).	1322 (31) [42.7]	3242 (38) [85.3]	5854 (59) [99.2]	10,880 (73) [149.0]	19,269 (103) 187.1]
# of articles in zone 3 (# of journals).	1326 (463) [2.86]	3213 (907) [3.54]	5987 (1268) [4.72]	10,989 (1982) [5.54]	19,218 (2951) [6.51]
Total # of articles (total # of journals)	3996 (502) [7.96]	9667 (953) [10.14]	17923(1339) [13.39]	32,897 (2070) [15.9]	57,627 (3072) [18.76]

[a] [.] Refers to # of articles per journal. (.) Refers to #of journals.

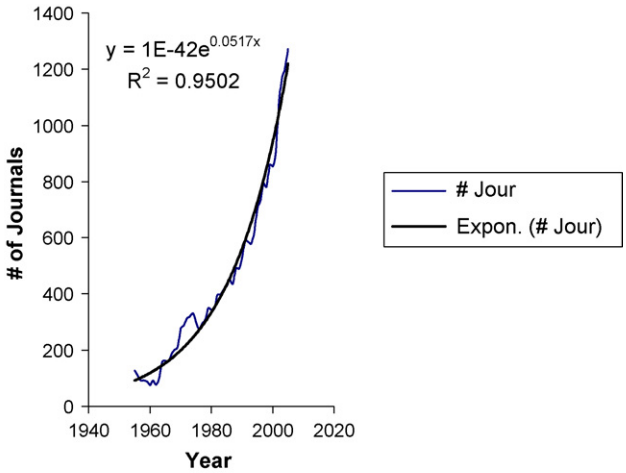

Fig. 1. Growth curve of Journals.

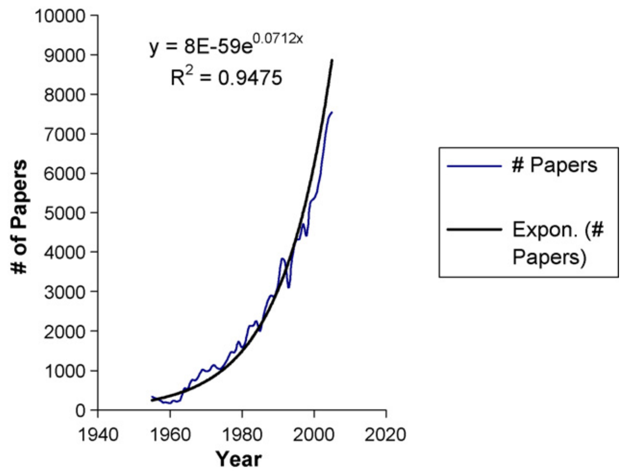

Fig. 2. Growth curve of Articles.

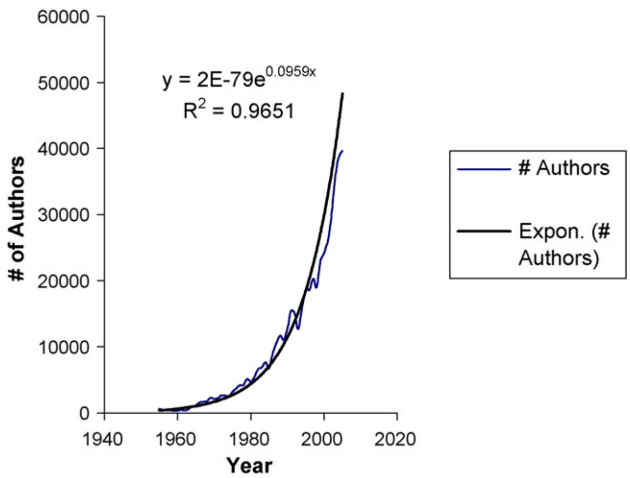

Fig. 3. Distribution of Authors.

observed data (Table 1). The analyses were carried out to choose the best regression equation (among the three), involving three variables:

1. Articles = $a_1 + a_2$*Journals + a_3*Authors.
2. Journals = $a_1 + a_2$*Articles + a_3*Authors.
3. Authors = $a_1 + a_2$*Articles + a_3*Journals.

The results are:

1. Articles = −39.2771 + 3.61719*Journals + 0.085882*Authors (R^2 = 99.16%).
2. Journals = 84.7129 + 0.13699*Articles + 0.003053*Authors (R^2 = 98.66%).
3. Authors = −2873.51 + 4.4767*Articles + 4.20186*journals (R^2 = 98.36%).

With regard to the first linear multiple regression equation, we have the following statistics:

Dependent variable: Articles (y)
Independent variables: Journals (x)
Authors (z)

Model is $Y = c + a^*x + b^*z$

Parameter	Estimates	St. error	*T*-Stat.	*P*-Value
Constant	−39.2771	90.5063	−0.43397	0.6663
Journals	3.61719	0.526763	6.86683	0.0000
Authors	0.085882	0.0156847	5.47552	0.0000

Analysis of variance

Source	Sum of squares	*df*	Mean square	*F*-Ratio	*P*-Value
Model	2.08501E8	2	1.0425E8	2838.59	0.0000
Residual	1.76286E6	48	36726.2		

R-Squared: 99.1616%.

The *R*-squared statistic indicates that the model as fitted explains 99.1616% of the variability in articles. The *P*-value of the independent variables (journals and authors) is 0.0000. Since it is less than 0.01, the highest order term is statistically significant at the 99% confidence level. Consequently, there is no need to remove any variables from the model! Thus, the regression equation Articles = −39.2771 + 3.61719*Journals + 0.085882*Authors may be used to estimate the number of articles. In this equation, the constant is negative and the coefficients are very small. Thus, it indicates that in order to have a small increase in the number of articles, it requires considerable increase in both the number of journals available and most productive authors.

With regard to the second linear multiple regression equation, we have the following statistics:

Dependent variable: Journal (x)
Independent variables: Articles (y)
Authors (z)

Model is $X = c + a^*y + b^*z$

Parameter	Estimates	St. error	*T*-Stat.	*P*-Value
Constant	84.7129	12.7262	6.65658	0.0000
Articles	0.136999	0.0199508	6.86683	0.0000
Authors	0.0030530	0.0038656	0.789788	0.4335

Analysis of variance

Source	Sum of squares	*df*	Mean square	*F*-Ratio	*P*-Value
Model	4.89879E6	2	2.44939E6	1760.91	0.0000
Residual	66767.1	48	1390.98		

R-Squared: 98.5994%.

The *R*-squared statistic indicates that the model as fitted explains 98.6554% of the variability in Journals. The *P*-value of the independent variable (authors) is 0.4335. Since it is greater than 0.01, the term is not statistically significant at the 99% or higher confidence level. Consequently, the variable 'authors' may be removed from the model! i.e., Journals = 84.7129 + 0.136999*Articles. It is then only a two-dimensional equation and the variable 'authors' has no affect on this linear model.

With regard to the third linear multiple regression equation, we have the following statistics:

Dependent variable: Authors (z)
Independent variables: Articles (y)
Journals (x)

Model is $Z = c + a^*y + b^*x$

Parameter	Estimates	St. error	*T*-Stat.	*P*-Value
Constant	−2873.51	506.596	−5.67218	0.0000
Articles	4.4767	0.817584	5.47552	0.0000
Journals	4.20186	5.32023	0.789788	0.4335

Analysis of variance

Source	Sum of squares	*df*	Mean square	*F*-Ratio	*P*-Value
Model	5.50884E9	2	2.75442 E9	1438.79	0.0000
Residual	9.1890E7	48	1.91439E6		

R-Squared: 98.3593%.

The *R*-squared statistic indicates that the model as fitted explains 98.3593% of the variability in Authors. The *P*-value of the independent variable (journals) is 0.4335. Since it is greater than 0.01, the term is not statistically significant at the 99% or higher confidence level. Consequently, the variable ‘journals’ may be removed from the model! It is again only a two-dimensional equation and the variable ‘journals’ has no affect on this linear model.

Thus, only the first multiple regression equation may be considered to explain the linear relation among the three variables—articles, authors and journals. This equation is therefore reasonably good to predict the number of articles for a given number of journals and authors. Below, Fig. 4 shows the curves for original data and for the estimated data. The data were estimated using the first multiple linear regression equation. It certainly indicates that the fit is good.

5.2. Growth of journals in least and most productive groups of Journals

In order to study the growth of journals (as well as the articles) in most and least productive groups, Journals were grouped into three zones, for a period of every 10 years from 1955 to 2005. The data is shown in Table 2. Zones were formed, as explained by Bradford (Bradford, 1934). He stated ‘if scientific journals are arranged in order of decreasing productivity of articles on a given subject, they may be divided into a nucleus of periodicals more particularly devoted to subject and several groups or zones containing the same number of articles as in the nucleus, when the zones will be 1: n: n^2...’

In Table 2, we may observe that:

- Core journals (in zone 1) increased from 8 in 55–65 to 18 in 96–05—two and half times in 50 years (linear growth).
- Articles (in zone 1) increased from 1348 in 56–65 to 19140 in 96–05—more than fourteen times; at the rate of 6.69% (computed under the assumption that articles increase exponentially; $R^2 = 0.9933$).
- Articles per journal (in zone 1) increased from 168.5 in 56–65 to 1096.7 in 96–05—more than six and half times; at the rate of 4.41% (computed under the assumption that articles per journal increase exponentially; $R^2 = 0.9536$).
- Least productive journals (in zone 3) increased from 463 in 55–65 to 2951 in 96–05—more than six times; at the rate of 4.55% (computed under the assumption that least productive journal increase exponentially; $R^2 = 0.9887$).
- Articles in least productive journals (in zone 3) increased from 3998 in 55–65 to 19,218 in 96–05—about five times; at the rate of 6.74% (computed under the assumption that least productive journal increase exponentially; $R^2 = 0.9931$).
- Articles per journal (in zone 3) increased from 2.86 in 56–65 to 6.51 in 96–05—2.3 times; (linear growth, $R^2 = 0.9941$).

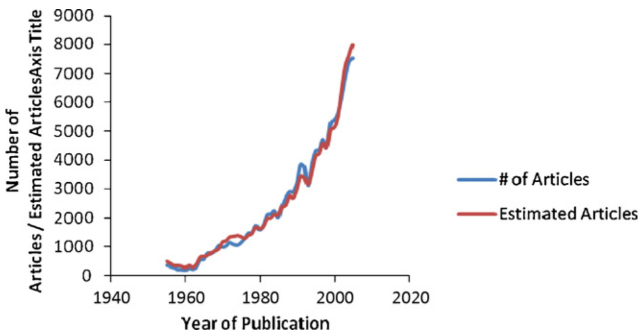

Fig. 4. Curves for the number of articles and for the estimated number of articles.

The growth patterns of journals and articles per journal in zone 1 and zone 3 are quite opposite to each other. Articles, however, increase exponentially irrespective of the zones.

6. Concluding remarks

Scientometrics is used to measure scientific activities, using statistics on scientific publications indexed in databases. They are flexible tools used to study the sociological phenomena associated with scientific communities, to conduct scientific/strategic, technical, technological or competitive monitoring, to design and manage research programs and to evaluate research. This study indicates that in the area of malaria research, journals, articles, and authors increase exponentially. The equation that Articles = −39.2771 + 3.61719*journals + 0.085882*Authors (R^2 = 99.16%) may be used to predict the number of articles based on the number of journals and authors.

This equation also indicates that in order to have a small increase in the number of articles, it requires considerable increase in both the number of journals available and most productive authors. The growth patterns of journals and articles per journal in productive group (zone 1) and least productive group (zone 3) are quite opposite to each other. Articles, however, increase exponentially irrespective of the zones. An important observation is that the number of least productive journals has been increased to 2951 from 463 (more than six times.) This is perhaps due to interdisciplinary nature of research in malaria and related topics and high growth rates (exponential in nature!) of journals, articles and authors.

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