BRADFORD'S EMPIRICAL LAW

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ABSTRACT

In the present paper an attempt has been made to study the various aspects of Bradford's Law. In respect to its concept, history, implications, verbal and graphical representation .It also emphasizes the application in the deriving the periodical subscription policy in the library.

Keywords: *Bradford Law, Bibliometrics and Laws of Bibliometrics*

1. Introduction

In recent days 'Bibliometrics' has commanded the attention of a number of individuals' in Library and information science. The measurement of bibliographic information offers the promise of providing a theory that will resolve many practical problems. It is claimed that patterns of author productivity, literature growth rates and related statistical distributions can be used to evaluate authors, to assess disciplines and to manage collections. Yet, it is unclear if it is merely a method or if it meets the test of a theory in its ability to explain and predict phenomena. Two concerns have occupied much of the bibliometric literature: an emphasis on mathematical or statistical methods, and a search for theoretical propositions. Fairthorne (1969), Price (1976) and Bookstein (1976) have stated that there is great consistency among the various bibliometric distributions. The Bradford (1934), Lotka (1926) and Zipf (1949) distributions are considered the basic laws of bibliometrics,' and each of these distributions was empirically derived. The distributions are similar to each other as special cases of a hyperbolic distribution.

Empirical laws are: i) Derived from experience or experiment; ii) Depending upon experience or observation alone, without using scientific method or theory; and iii) Verifiable by experience or experiment. Hence these three laws have been called empirical laws. In the present paper an attempt has been made to study the Bradford's Law.

2. History of Bradford's Law

Samuel Clement Bradford (10 January 1878 – 13 November 1948) was a British mathematician, librarian and documentalist at the Science Museum in London. He developed Bradford's law" (or the "law of scattering") regarding differences in demand for scientific journals. This work influences bibliometrics and citation analysis of scientific publications. Bradford founded the British Society for International Bibliography (BSIB) in 1927 and he was elected President of International Federation for Information and Documentation (FID) in 1945. Bradford was a strong proponent of the UDC and of establishing abstracts of the scientific literature.

Bradford's law of scattering , first published in 1934, is often mentioned together with Zipf's law (about word frequencies in natural language texts) and Lotka's law (about distribution of authors' productivity) as one among the three most important bibliometric laws, and is often considered the best model or example of

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scientific research that is available within Library and Information Science (LIS). Bradford's law states that; documents on a given "subject" is distributed (scattered) according to a certain mathematical function so that a growth in papers on a subject requires a growth in the number of journals/information sources. The number of the groups of journals to produce nearly equal number of articles is roughly in proportion to 1: n: n2 ..., where n is called the Bradford multiplier. Bradford's Law states that a small core of, for example, journals have as many papers on a given subject as a much larger number of journals, n, which again has as many papers on the subject as n^2 journals.

Bradford studied the title dispersion of useful papers in two areas: applied geophysics and lubrication by arranging the source titles in order of productivity and then dividing them into three approximately equal groups. Bradford concluded that the ratio of the titles in successive zones followed a common pattern, and proposed and following "law of scattering".

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 the subject and several groups of zones containing the same number of articles as the nucleus where the number of periodicals in the nucleus and succeeding zones will be 1: a: a

In other words, only a small number of journals will be needed to supply the nucleus of paper on a given topic, assuming that the topic is a narrow scientific subject. Beyond the nucleus or first zone, however, the number of journals required to produce the number of papers increases dramatically. For example, if two journals are needed to supply the next 300articles, sixteen journals will be needed to supply the next 300 articles.

While preparing bibliographies we were faced with the problems of coverage the journals that are to be scanned, etc. Bradford's distribution can be fruitfully used to estimate the total size of a bibliography and the periodicals that should necessarily be included in the list of items to be covered.

On the application side of this law, the studies of Goffman and Morris (1970) are significant. Goffman and Morris found that the pattern of journal usage in the Allen Memorial Library follows Bradford's distribution.

3. Implications

The statistical regularity pointed out by Bradford's law provides an objective means of determining zones of relative richness or value to a given kind of library collection. This has implications to the acquisition process in a library. A library can safely stock the journals which belong to the core or nuclear zone. It is advisable to extend the purchase list to the next zones till the budget limits permit. If at all the budget is elastic, a point will be reached at which it would be desirable to obtain copies of articles in the journals on demand rather than subscribing to the journal. Lancaster provides an excellent hypothetical example of applying Bradford's law in periodical collection building, while discussing the principle of diminishing returns Brookes (1969) is of the view that if the total expenditure on periodical provision is limited to the fraction 'f' of the sum needed to cover the subject completely, the buying of periodicals may be supplemented by the buying of photocopies of the relatively few relevant papers published in the peripheral periodicals.

What are the implications of the three kinds of scattering for the practical use of Bradford's law? If core journals (or other information sources) are selected from the frequencies of words or concepts, rather than subjects proper, then such cores may contain journals that are not relevant to users. The core may be "polluted" with

journals not belonging to "the subject". Such journals may take the place of other journals "on the subject" that use different words or concepts. In other words, an adequate indexing of documents is as relevant for providing Bradford distributions as for providing relevant documents to users. Besides, while the distribution of documents according to word frequencies is a rather mechanical, neutral, and "objective" process, the distribution of information sources according to subject matter is a much more interpretative and political process. It is much more difficult to make operational implications of "subjects". What is a subject for one person need not be the same subject for another. The best way to generalize views about subjects is probably to consider different theoretical views or epistemologies regarding subjects. A pure mechanical view of selection must consequently be replaced by a reflective view in which the selector must justify the selection on value based studies.

4. Applications of Bradford's Law

Brookes (1968) was among the first to address the possible applications of Bradford's law. In a short note in Nature he wrote that the law "seems to offer the only means discernible at present to reducing the present quantitative untidiness of scientific documentation, information systems and library services to a more orderly state of affairs capable of being rationally and economically planned and organized".

Several commentators have suggested solving practical journal collection management problems by using Bradford's law. The basic idea is to conduct Bradford analyses of journals - i.e., to sort out to the journals in Bradford zones – and thus to identify which belong to the core and which do not. Any Bradford analysis involves three steps

1. Identify many or all items (usually articles) published in this field;
2. List the sources (usually journals) that publish the articles (or items) in rank order beginning with the source that produces most items;
3. While retaining the order of the sources, divide this list into groups (or zones) so that the number of items produced by each group of sources is about the same.

Nisonger (2008) argues in his textbook Management of Serials in Libraries that the following points are some of the "most obvious potentials" of Bradford analyses:

a) Selection/deselection;
b) Defining the core;
c) Collection evaluation;
d) The law of diminishing returns;
e) Calculation of cost at various coverage; and
f) Setting priorities among journals.

A study conducted by Garg and Lalitha Sharma, (1994) of R & D indicators in Indian industry using Bradford's law, bears testimony to this fact. By analyzing the R & D expenditure of 452 in –house R & D units, there is a heavy concentration of manpower deployed, papers published, patents field, processes/products developed in the core in-house R & D units. This shows the superiority of the core not only in the R & D expenditure but also in other yardsticks too.

The current revolution in computer-aided, micro analytical techniques of information retrieval is largely justified by earlier studies of literature used in scientific research. These studies showed that a researcher's interest was widely scattered among formal titles and classifications and was much more extensive provided by exist than the coverage provided by existing bibliographic services. The important measures of scatter used in empirical studies are "title dispersion", which is defined as the degree to which the useful literature of a given subject area is scattered through a number of different books and journals.

In comparing cumulative periodicals with the cumulative references they yield, Bradford proposed the linear logarithmic approximation. Vickery (1948); shows that Bradford's law is independent of the number of the zones chosen. However, this affects the value of the ratio multiplier.

A more revealing analysis of title dispersion can be made by first evolving the mathematical formal for the distribution of references in an ordered collection of titles, which is implicit in Bradford's Law. This formula, make it possible to use standard statistical methods for summarizing empirical data and making tests of hypothesis.

Bradford did not conclude his study by simply stating his law verbally, but went to express it graphically by using experimental data, not noting himself that the graphical expression was not mathematically identical to verbal formulation. He plotted R (n) (cumulative total of relevant papers) against log n (natural logarithms of total of productive journals) and found that the data revealed an elongated s-shaped curve, the general form of which is shown in the figure. Part one of the curve, the initial concave portion, represents the higher density of the nuclear zone. Part two, the linear portion of the curve when data are plotted on a semi log scale, is equivalent to Zipf (1949) distribution. Hence the commonly used expression the Bradford- Zipf distribution part three, often called the 'Groos drop', shows a departure from linearity for higher values of n, the reason for which is not yet fully understood (Groos, 1967). Brookes (1968), thought that the droop observed when there were omissions from the relevant literature (Figure – 1).

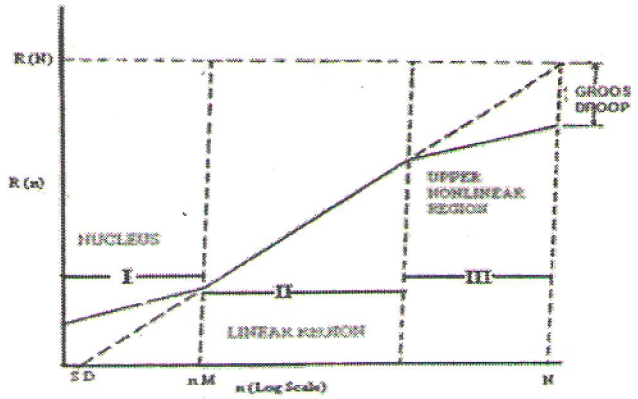


Figure – 1.Groos Droop (Source: Sangam, 1985)

In the years following the publication of Bradford's Law papers by eminent researchers such as Vickery (1948), Brookes (1968) and Leimkuhler (1967) contributed to a partial understanding of the Bradford distribution partially because these contributors did not interpret the law in mathematically identical terms. Vickery extended the verbal formulation to show that it could be applied to any number of zones of equal yield, not

only to the three zones that Bradford had used for his date (Vickery, 1948). Later Leimkuhler expressed the verbal formulation mathematically as is shown in the equation (Leimkuhler, 1967).

$$R(n) = j \log (n/t+1) \quad (n>n_m)$$

Where

R (n) =cumulative total of relevant papers found in the first n journals when

all periodicals are ranked 1, 2,3…n in order of decreasing productivity:

n = Cumulative number of journals producing

R (n) = relevant papers;

j and t =Constants defined in terms of others variables; and

n_m = the value of n beyond which the curve becomes linear.

Brookes in a study expressed the formula for the graphical version of Bradford's law beyond the nuclear zone and for N log as is shown in equation 2 (Brookes, 1968).

$$R(n) = N \log (n/s) \quad (n>n_{m)}$$

Where

N=total number of journals estimated to contain articles relevant to the subject of the search.

S= a constant calculated using experiment data.

Vickery (1948) in his paper noted that the verbal and graphical formulations were not mathematically identical. Once the disparity between the two formulations was recognized, the question arises concerning which of the two was more practical to apply to empirical data. Wilkinson (1972) devised a comparative test between the two formulations utilizing the same bibliographic data for four different subjects (agricultural, economics, muscle fiber, schistosomiasic, and mast cells. The test did not require calculation of the nucleus (region 1 in figure 1). Instead, it utilized simple formulas for calculating N (the estimated total number of Journals containing articles relevant to subject of the search) and R (N) (the estimated total number of papers produced by N). Only 'P' (number of journals) and 's' (the corresponding cumulative number of papers) had to be known in order to apply the formulas. Both P and S were obtained from a plot of the empirical data on semi log paper. Although the value of P could be chosen anywhere in the linear portion of the curve, the point at which the initial concave portion of the curve turned into the linear region ($n= n_{m)}$ was arbitrarily chosen to be equal to P and was used in determining the corresponding value of S. By identifying the plot 2S papers, the corresponding number of journals required to supply 2S, called q, was ascertained. The values obtained for S, P, and q, were then used for calculating N and R (N) for both the verbal and graphical expressions of Bradford's law. Wilkinson's (1972) test revealed that, the data she considered the graphical rather than the verbal formulation was more consistent with the practical situation.

Verbal Formulation

$$N = \frac{S}{\log a} - \frac{P}{a - 1}$$

Where

$$a = \frac{q - p}{p}$$

$$R(N) = \frac{a}{\log a} \log \left[\frac{s}{\log a} - \frac{(a-1)}{p} \right]$$

Graphical Formulation

$$N = \frac{S}{\log \hat{a}}$$

Where $\hat{a} = \frac{q}{p}$

$$R(N) = \frac{S}{\log \hat{a}} . \log \left[\frac{a}{\log \hat{a}} \quad \frac{\hat{a}}{p} \right]$$

5. Test of Verbal and Graphical representation of Bradford's Law by Sangam

Purpose

Sangam (1985), tested the Leimkuhler's formula in his Ph.D thesis. The purpose of this investigation is to two-fold. First the study curves as a test of the two formulations of Bradford's law, verbal and graphical; to determine which one better fits citation data to the psychology.

Hypothesis

HO: Data fits with Bradford's Law of distribution

H1: Data doesn't fit with Bradford's law of Distribution

Result

The Bradford's Law was applied to the data of psychology and relevant statistics were computed by using the Leimkuhler's equation which is stated as follows: (Sangam, 1985).

$$P(x) = \frac{\log (1+\hat{a}x)}{\log (1+\hat{a})}$$

Where â is connected with x as follows

$$x = \frac{1}{\log (1+\hat{a})} - \frac{1}{\hat{a}}$$

$$\text{Ó if (i)} = \frac{\text{Ó if (i)}}{\log (1+\hat{a})}$$

Ó if (i) = 0.2692754 (computed from Table 30.2). Using the trial and error method and from equation (30.2) we found the value of.

$$= \frac{0.2692754}{x \log (1+\hat{a})}$$

substituting Ó if (i) = 0.2692754

$$\hat{a} = 23.871135$$

Equation (1) can be written as,

$$P(x) = \frac{1}{\log (1+\hat{a})} \log (1+\hat{a}x)$$

$$\frac{1}{\log (1+23.871135)} \log (1+23.871135x)$$

$$= [0.311167] [\log (1+\hat{a}x)]$$

Where

$$\frac{1}{\log (1+\hat{a})} = 0.311167$$

The maximum of the absolute differences between expected and observed values is found to be

$$D = \text{Max} \quad P(x) - \hat{P}(x)$$

where P (x) = observed values

$\hat{P}(x)$ = Theoretical values

$$= 0.066516$$

At 5% level of significance for n=30, the table value of $D_{\acute{a}} = 0.242$

Since D e" $D_{\acute{a}}$

The data obtained in the study were put to test the law of scattering.

Accordingly, Graph was plotted by taking cumulative sum of articles R (n) ðn the ordinate 'x' – axis versus the log of the cumulated sum of journals on the 'y' axis (Figure-.2).

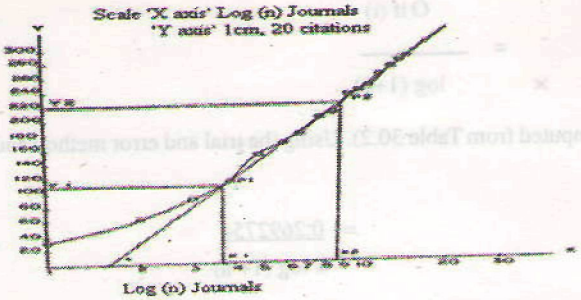


Figure –2. Cumulative sums of articles versus the log of the cumulative sum of journals

An initially raising and then turning into a linear curve was obtained as shown in the graph. This is accordance with Bradford's hyperbolic curve and therefore it can be said that Bradford's law holds good with psychology journals.

Table - 1 Citation data for Psychology Journals, Theoretical and observed value

Theoretical Value		Observed Value	Difference
X	A/P(X)	P(x)	P(x)-A/P(x)
1	2	3	4
0.03	0.1680532	0.1209	0.0471532
0.06	0.2765727	0.2206	0.0559727
0.10	0.3796169	0.3131	0.0665169
0.13	0.4392989	0.4021	0.0371989
0.16	0.4893554	0.4733	0.0160554
0.20	0.5456015	0.5444	0.0002
0.23	0.5819812	0.5943	0.123188
0.26	0.1645494	0.6405	0.0259506
0.30	0.6532666	0.6761	0.0228334
0.33	0.6794384	0.7117	0.322616
0.36	0.7035788	0.74377	0.0401912
0.40	0.733103	0.7722	0.039097
0.43	0.7535419	0.8007	0.0471381
0.46	0.7727706	0.8291	0.563294
0.50	0.7965815	0.8505	0.539185
0.53	0.8133482	0.8685	0.0549518
0.56	0.8292575	0.8825	0.0532425
0.60	0.8492787	0.8967	0.0474213
0.63	0.863492	0.9110	0.047508
0.66	0.8770844	0.9252	0.0481156
0.70	0.8943306	0.9359	0.0415694
0.73	0.9066655	0.9466	0.0399345
0.76	0.9165301	0.9572	0.0386695
0.80	0.9336771	0.9679	0.0342229
0.83	0.9445722	0.9750	0.0304278
0.86	0.9550968	0.9822	0.0271012
0.90	0.9686021	0.9893	0.0206979
0.93	0.9783585	0.9928	0.0144415
0.96	0.9878182	0.9964	0.581803
1.00	0.9999998	1.00	-2.-07

(Source: Table 30, page, 157, Sangam, 1985).

Table - 2

X		P(x)	
1/30	=0.03	34/281	=0.1209
2/30	=0.06	62/281	=0.2206
3/30	=0.1	88/281	=0.3131
4/30	=0.13	113/281	=0.4021
5/30	=0.16	133/281	=0.4733
6/30	=0.20	153/281	=0.5444
7/30	=0.23	167/281	=0.5943
8/30	=0.26	180/281	=0.6405
9/30	=0.30	190/281	=0.6761
10/30	=0.33	200/281	=0.7117
11/30	=0.36	209/281	=0.74377
12/30	=0.40	217/281	=0.7722
13/30	=0.43	225/281	=0.8007
14/30	=0.46	233/281	=0.8291
15/30	=0.50	239/281	=0.8505
16/30	=0.53	244/281	=0.8683
17/30	=0.56	248/281	=0.8825
18/30	=0.60	252/281	=0.8969
19/30	=0.63	256/281	=0.9110
20/30	=0.66	260/281	=0.9252
21/30	=0.7	263/281	=0.9359
22/30	=0.73	266/281	=0.9466
23/30	=0.76	269/281	=0.9572
24/30	=0.80	272/281	=0.9679
25/30	=0.83	274/281	=0.9750
26/30	=0.86	276/281	=0.9822
27/30	=0.9	278/281	=0.9893
28/30	=0.93	279/281	=0.9928
29/30	=0.96	280/281	=0.9964
30/30	=1.00	281/281	=1.00

(Source: Table 30.1, page, 161, Sangam, 1985).

Table - 3

No. of Journals	No. of Citations	
i	f(i)	if(i)
1)	34/281=0.120996	0.120996
2)	28/281=0.099644	0.199288
3)	26/281=0.092527	0.277581
4)	25/281=0.088968	0.355872
5)	20/281=0.071174	0.3558718
6)	20/281=0.071174	0.427044
7)	14/281=0.049822	0.348754
8)	13/281=0.0462633	0.3701064
9)	10/281=0.0355871	0.3202839
10)	10/281=0.0355871	0.3558710
11)	9/281=0.0320284	0.3523124
12)	8/281=0.0284697	0.3416364
13)	8/281=0.0284697	0.3701061
14)	8/281=0.0284697	0.3985758
15)	6/281=0.213523	0.3202845
16)	5/281=0.0177935	0.284695
17)	4/281=0.0142348	0.2419916
18)	4/281=0.0142348	0.2562264
19)	4/281=0.0142348	0.2704612
20)	4/281=0.0142348	0.284696
21)	3/281=0.0106761	0.2241981
22)	3/281=0.0106761	0.2348742
23)	3/281=0.0106761	0.2455503
24)	3/281=0.0106761	0.2562264
25)	2/281=0.2271174	0.177935
26)	2/281=0.2271174	0.1850524
27)	2/281=0.2271174	0.1921698
28)	1/281=0.0035587	0.0996436
29)	1/281=0.0035587	0.1032023
30)	1/281=0.0035587	0.106761

(Source: Table 30.2, page, 162, Sangam, 1985). [Sum of if (i) = 8.078266/30=0.2692754]

1. Library Acquisition Policy Based on Bradford's Law

Goffman and Morris (1970) found that distributions of both circulating periodicals and their users in a medical library seemed to obey Bradford's law. Much of the untidiness mentioned by Brookes (Brookes, 1970) is attributed to the lack of methods for determining the minimum size or lower limits of a useful library collection, using Bradford's Law; they have suggested a method for establishing such a lower limit for the purpose of maintaining a dynamic library collection.

Bradford's law, although an interesting phenomena, was of little practical use. It was shown, however, that there is a numerical nucleus in the sense of Bradford. That is, a core of journals can be separated from the top of an ordered list of periodicals dealing with a given subject which represents the most significant information sources for that field. Moreover this numerical nucleus, does not necessarily consist of only the most productive periodicals, but may contain any number of journals depending on the extent of dispersion of the subject's

literature among the various periodicals. Thus it is possible to set lower bounds on the number of journals which must be contained in a collection devoted to a given subject.

Nucleus of Journals

Brookes (Brookes, 1970) has also pointed out that Bradford's law can be expected to arise when selection is made of items, characterized by some common for an equal period and subject to the "success-breeds-success" mechanism. Hence, Bradford's law should apply to the use of periodicals in a library as well as to the dispersion of articles among journals. These are both acquisition processes, namely, process of obtaining relevance by means of selection.

Acquisition Policy

Taking into consideration the assumption that journal circulation obeys Bradford's law, the following acquisition policy can be derived. In doing so it is important to base the selection of journals on expected future demand-

1. First establish the numerical nucleus and its successive zones of periodicals circulating at various successive time intervals. The length of these intervals will vary from library to library with the destiny of use. Some libraries may complete the nucleus each month, others every three months, and so forth. This is necessary because the nucleus may vary with time as a remit of change in users interest.
2. On the basis of these observations, establish the rate of change of circulation for each periodical circulated in the library.
3. On the basis of three rates of change, establish by any appropriate means of extrapolation the expected circulation at some appropriate future data, say a year in advance.
4. The expected numerical nucleus should then belong to the numerical collection in the library's inventory at that point in time.
5. As a safety factor, it may be a good policy for the library not to delete a given journal from its collection until its predicted decline in circulation is verified by fact.

2. Nucleus of Users

If the budget allows, it may be in the library's interest to include those periodicals which are of greatest interest to its best customers, provided that they do not already appear in the nuclear nucleus of the circulating journals. The successive zones of users borrowing about the same number of journals formed a geometric series. Thus we can:

i. Establish the numerical nucleus of the users of the library;

ii. Determine the areas of interest of the members of this nucleus, in terms of, for example, *Social Science Citation Index. For Social Science Research Scholars*. This can be done by selecting the headings of SSCI under which their most recent publications have been indexed. For social science research scholars, teachers and students, this may be done by interest profiles.

iii. Establish the numerical nucleus for each subject heading represent by the user nucleus. This is done by applying Bradford's law to the distribution of articles among journals under each of the subject headings.

iv. The totality of such numerical nucleus should then be added to the numerical nucleus of circulating journals for the library's numerical collection

v. The expected numerical nucleus of users as well as the expected numerical nucleus of the subject areas of their interest at some appropriate future date can be established by extrapolitation, and in this way the library can be in a position to anticipate future demand. In this case it may be good policy to include some new titles in the collection on the basis of these predictions.

3. Conclusion

Bibliometrics has much to offer to the library and information field. The work of the past-by Lotka, Bradford and Zipf-is valuable in helping librarians assess patterns of authorship (for cataloguing rule changes), identifying core collections (for collection management), and designing better retrieval systems (for authority control). However, the continued emphasis on the similarities of the bibliometric statistical distributions is not regarded here as a fruitful endeavour. The long-term benefits of bibliometrics will begin to emerge when attention is directed toward causal explanations of bibliographic phenomena. At that point, bibliometrics will again offer practical benefits to libraries.

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