FIFTH INTERNATIONAL CONFERENCE OF THE INTERNATIONAL SOCIETY FOR SCIENTOMETRICS AND INFORMETRICS

PROCEEDINGS—1995

June 7-10, 1995

Sponsored by

ROSARY COLLEGE
GRADUATE SCHOOL OF LIBRARY & INFORMATION SCIENCE
RIVER FOREST, ILLINOIS
USA

Edited by
Michael E.D. Koenig
Rosary College
&
Abraham Bookstein
University of Chicago

Learned Information, Inc.
Medford, NJ

Published for the International Society for Scientometrics and Informetrics by Learned Information, Inc.

Manufactured in the
United States of America

ISBN: 1-57387-010-2
Price: $79.00
Order from: Learned Information
143 Old Marlton Pike
Medford, NJ 08055
USA

Proceedings Manager: Carol Nixon
Cover Design: Jennifer Johansen

The papers published in this volume are in the format submitted by the authors. No editorial intervention was undertaken by the Editors unless absolutely necessary and only if the production schedule allowed. The Editors' task was to solicit contributions and to assist in other editorial matters.

QUALITY AND DISTRIBUTION OF AUSTRALIAN SCIENCE JOURNAL PUBLISHING

Pamela L. Royle and Gary E. Davis
La Trobe University, Bundoora, Victoria, Australia

Keywords: Australia, impact factors, science journals, distributions, quality.

Abstract: We address the question of the changing patterns of Australian science journal publishing and the quality of journals in which Australian authors publish, as indicated by the impact factors of the journals. Our technique is to weight the number of Australian authored articles in a given journal by the impact factor of the journal. We sum over all journals and normalize by the average number of citations per world article. We plot this statistic for more than a decade and show that is approximately constant at 1.2 . We also obtain detailed distributions of Australian science journal publishing from 1983 - 1993, and obtain quantitative relationships that are exemplified by power law distributions. These distributions are compared with those for a number of other countries from 1990-1993. We discuss a general model for science journal publishing that suggests the distributions we examine should possess the fractal character that is observed.

1. INTRODUCTION

There has been evidence advanced recently that Australia's scientific research effort is in a state of decline (Bourke and Butler[1], Science Watch[2]). The statistic most often used to measure this decline is the rate of citation of Australian scientific authors by international authors. In two recent papers one of us (Royle[3]; Royle and Over[4]) examined the use of bibliometric indicators to measure the research productivity of Australian academics, and carried out a citation analysis of Australian science and social science journals. Bourke and Butler[1] examine the productivity and citation impact of Australian science over the period 1982-1991. Their analysis is based on a general graphical trend in a short segment of a time series. They point out the difficulty in using this technique when they say: "This is not a lengthy period, by the standards of other time series research, ..." (p. 1)

Hill and Murphy[5] provide data from research reports of 36 institutions of higher education. They list journals in which Australian academics published 10 or more articles in 1991, and the numbers of articles they published in those journals. From their list of journals we selected those which were Science Citation Index (SCI) source journals and ranked them by the number of articles with Australian academic authors (highest number of publications = rank 1). We find, using linear regression, that approximately 98% of the variation in the logarithm of the number of articles can be accounted for by variation in the logarithm of the rank. By comparison, the distribution of total source articles to the same journal set is roughly exponential over a large range of about 30 to 5,000 source items.

In this article we re-consider the problem of ascertaining the changing nature of Australian science journal publishing. Following on the Bourke and Butler[1] study we address the question of the changing patterns of this activity and the quality of journals in which Australian authors publish, as indicated by the impact factors of the journals. We then make a case for a statistic related to the quality of a journal that has the impact factor as a component.

Secondly, starting from Hill and Murphy's[5] study, we obtain a detailed distribution of Australian science journal publishing for each of a number of years, with a view to obtaining quantitative relationships that are exemplified by power law distributions. Such distributions are widespread in informetric studies: see, for example, Naranan[6,7], Haitun[8,9], Brookes[10], Egghe[11]. The existence of power law distributions allows a comparison of Australian and international science publishing that is based on the changing parameters of these distributions. We are concerned to detail - year by year - the distribution of Australian authored articles (those with one or more Australian addresses) across SCI journals, and to compare this with similar distributions for other countries. The average height of buildings in a city tells us one thing: the distribution of heights tells us more. Similarly, because of the highly skewed nature of science journal publishing, a distribution of Australian authored articles across journals tells us much more than a simple average. Finally we will discuss a general scenario for science journal publishing that, without going into mathematical details, suggests the distributions we examine should possess the fractal character that is observed.

2. METHODOLOGY

Data for this study was downloaded from the SCI on CD-ROM (Institute for Scientific Information,1982-1993). We included all types of source items (articles, meeting abstracts, notes, letters, etc.: see Science Citation Index, 1993 Annual). In this we follow Leydesdorff[12], p.113, who advocated using all document types because "... we do not yet know how to attribute relative weights to types of documents in national performance measurement." The *year* of each article was taken to be the year of the SCI CD-ROM in which it was included (as opposed, for example, to publication year). We counted an article as Australian authored exactly when it had at least one author with an Australian address. We adopted a similar procedure for other countries, so, for example, an article with both an Australian and Swedish author is counted twice: once as an Australian publication and again as a Swedish publication. An article with two or more Australian authors is, however, counted only once as an Australian authored article. Journal impact factors, citations, and citings, were obtained from the SCI Journal Citation Reports (SCI JCR) from 1982 through 1993. The data from which the source publications and total source items were obtained came from the SCI Comparative Statistical Summary (1982-1993) in the SCI Source Publication Data for 1993.

3. CHANGING PATTERNS OF AUSTRALIAN SCIENCE PUBLISHING

We define the *reach* of a region or country into SCI journals to be the percentage of SCI source publications containing at least one article with an author address from that region or country. Australia's reach has generally been climbing since 1982. Furthermore, this reach has been accompanied by a move away from Australian based science journals, and increasingly to other journals as the following plots show:

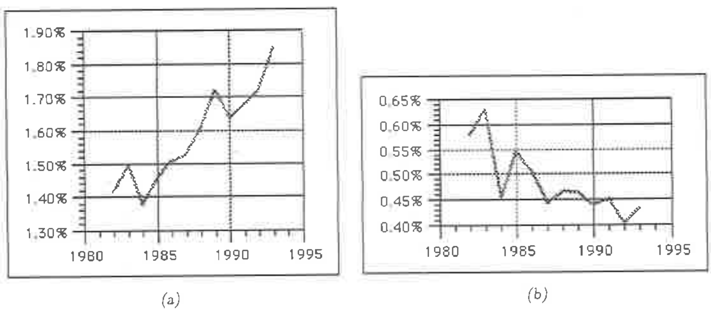

Figure 1. Plots of (a) Australian output, as % of world output, in non-Australian journals, and (b) % Australian output in Australian journals, 1982-1993

Whilst the figures shown in (a) are generally increasing and those in (b) generally decreasing, their *sum* - the percentage of SCI source items with one or more Australian authors - has generally been on the increase: from 1.99% in 1982 to 2.28% in 1993. One can reasonably argue therefore that not only is Australian science journal publishing relatively on the increase, but it is also becoming more international. Since we know that the Australian share of world citations is falling (Bourke and Butler[1], Science Watch[2]), this begs the obvious question of the *quality* of the journals in which Australians are publishing. The vexed question of how one might measure the quality of a journal is something we address in a later section. For now we simply use the *impact factor* as a rough indicator of quality. We want to estimate whether Australian articles are generally appearing in journals with higher or lower impact factors, as a function of time.

We define a statistic which, based on impact factor as a quality indicator, gives us a measure of the overall quality of journals in which Australian authored articles appear. Our procedure is as follows:

1. Multiply the number of Australian science articles in a journal by the impact factor of that journal and then sum over all journals: this gives us the *weighted impact sum* (WIS).

2. Divide the weighted impact sum by the total number of Australian articles for that year. This gives us a number whose units are "citations per article".

3. Divide this figure by the changing annual global imapct factor: the total number of citations to all journals in the previous two years, divided by the total number of articles in those two years. This is to adjust for a corresponding change in world impact factors: it's one thing to assert that the mean number of citations per Australian article is on the increase, but we need to adjust due to the increasing mean number of citations per article worldwide. In other words, $\kappa = \frac{WIS}{N \times <IF>}$ where N is the total number of Australian articles for the year, and $< IF >$ is the global mean impact factor. We calculated the statistic κ for Australia for the years 1983 through 1993. The results are as follows:

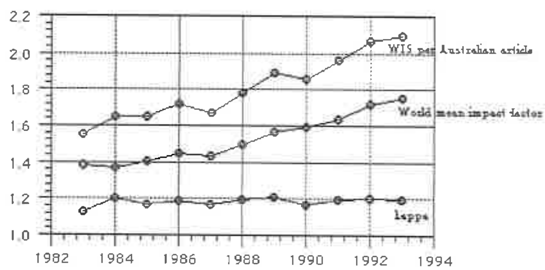

Figure 2. The statistic κ for Australia, 1983-1993

The statistic κ is approximately constant - at about 1.2 - from 1984 through 1993. The consistency of this statistic should be contrasted with the data of Bourke and Butler[1] which indicates that the Australian share of world citations showed a decline between 1988 and 1991. That is, despite an apparent decline in citation rates, Australian authored articles are consistently appearing in journals with an average impact factor 1.2 times the world average.

Another technique to obtain quantifiable information about the impact factors of journals in which Australian authored articles appear is to examine, for any given year, the covariation in the percentage of Australian output that appears in journals of a given impact factor, with that impact factor. We denote the number "*fraction of Australian output that appears in journals with impact factor x or more*" by $IF_{Aus}(x)$. When we plot $IF_{Aus}(x)$ versus x for 1988, for example, we obtain a distribution with the not atypical form shown in (a) below. A restricted plot with $0 \leq x \leq 5$ shows the existence of naturally occuring breaks in this plot, with the first break near $x = 1$. A plot of $IF_{Aus}(x)$ versus x for $0 \leq x \leq 1$ for the same year yields approximately a straight line, shown in (b) below:

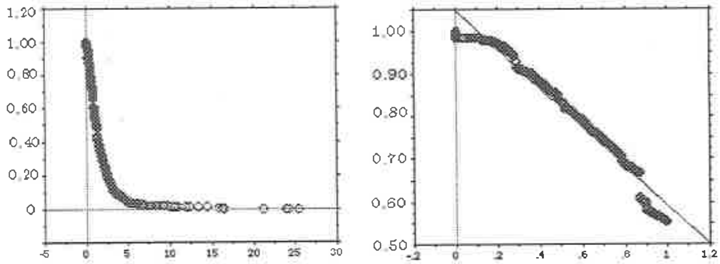

Figure 3. (a) $IF_{Aus}(x)$ versus x (b) $IF_{Aus}(x)$ versus x for $0 \leq x \leq 1$

A similar situation obtains for each of the years 1987, 1988, 1991, 1992 and 1993. These straight lines all intersect the vertical axis at approximately 1 (as they should) and their slopes vary as shown below:

Year	1987	1988	1989	1990	1991	1992	1993
Slope	-0.494	-0.459	-0.499	-0.48	-0.432	-0.376	-0.385
r^2	0.972	0.964	0.976	0.961	0.974	0.984	0.984

Table 1.

A hypothetical slope close to 0 indicates a distribution in which *almost all* articles appear in journals with impact factor 1 or more, whereas at the other extreme a very steep slope indicates a distribution in which almost all articles appear in journals with very low impact factor. The generally *decreasing* character of the absolute values of these regression lines indicates therefore, that the impact factors of journals in which Australian authored articles are appearing is generally *increasing* anually.

4 UNTANGLING THE IMPACT FACTOR

The use of citations and impact factors to measure the relevance, or importance, of journals to a scientific community depends, of course, on a data bank such as that compiled by ISI, and so is a relatively contemporary phenomenon. As recently as 1988, Todorov and Glanzel[13] (p. 47) commented on the utility of citation measures in ranking journals:

"Many librarians, information scientists and sociologists of science already consider journal citation analysis as a practical alternative to subjective judgement. Authors may take citation measures from JCR and use them as possible indicators of journal characteristics. Lists of ranked SCI journals may help potential and real users to identify sources with significant contributions."

A number of authors have developed indicators of journal usefulness and prestige - Bennion & Karschamroon[14], Sengupta[15], and Deurenberg[16], for example. Typically these indicators *are* used systemically, and even systematically, to make policy decisions - to decide, for example, which journal subscriptions to renew, or to evaluate academic publications by virtue of their being published in certain journals.

Here we present a case for a statistic that, for these purposes, seems to have some practical advantages over impact factors or citation counts alone. The problem can be seen clearly in a comparison of ten plant science journals (as defined by SCI): *Acta Botanica Neerlandica, American Journal of Botany, Annals of Botany, Australian Journal of Botany, Australian Journal of Plant Physiology, Botanical Journal of the Linnean Society, Canadian Journal of Botany, Canadian Journal of Plant Science, Journal of Plant Physiology* and *Netherlands Journal of Plant Pathology*. For the period 1980 through 1993 the impact factors for these journals varied substantially. When we plot the impact factors of all these journals on the one graph we get a quite scrambled picture:

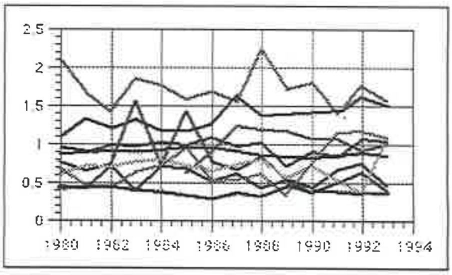

Figure 4. Impact factors by year for 10 SCI plant science journals

Notice two things about this picture: first the impact factors vary substantially in some cases from year to year. Secondly, the line graphs for different journals are interleaved and scrambled.

In order to provide a degree of smoothing and "untangling" of these plots we define a statistic σ as follows:

$$\sigma = log_2(c) + IF + r$$

where c is the number of annual citations to a journal, IF is its impact factor, calculated over the previous 2 years, and r is its percentage self-citing to percentage self-citedness ratio. Note that the percentage self-citing to percentage self-citedness ratio is the same as the cited:citing ratio.

We think of σ as a measure of the international relevance, importance, or usefulness, of a journal. This is because the three factors that enter into its definition - citations, impact factor, and cited to citing ratio - themselves are regarded as measures of attributes that contribute to international standing. The number of citations a journal receives in a year can be viewed as a measure of the relevance of the journal to the international commnuity; the impact factor weights citations by the number of journal articles and is, formally, an average citation rate (although this average is not so meaningful as an average due to the inherent skewness of citation rates; see, for instance, Seglen[17]); whilst the cited to citing ratio is a measure of the non-insularity of a journal or of the centrality of the field represented by the journal (Todorov & Glanzel[13], Garfield[18]). The logarithm of the number of citations is more useful for our purposes for several reasons:

* the logarithm is an increasing function and so preserves rank order when journals are ranked by citations;
* the citation count is roughly log-normally distributed, so the logarithm of the citation count is roughly normally distributed;
* the logarithm of the citation count varies, for quite a number of journals, roughly linearly with the number of the year in which the citations were made.

The changing σ values for the same ten journals over the same period are shown below in Figure 5 and Table 2, below:

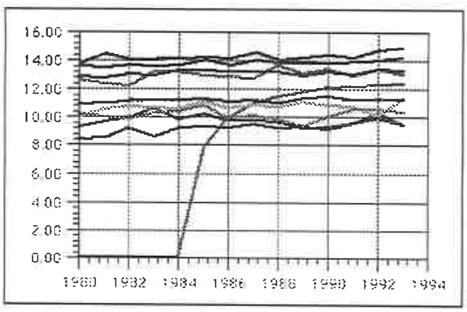

Figure 5. A plot of σ for 10 plant science journals, 1980-1993

Year	ABN	AEL	AH JB	AUS JB	AJPP	BJLS	CJB	CJPS	JPP	NJPP
1980	10.25	12.83	13.82	10.07	12.64	8.40	13.53	10.91	0.00	9.32
1981	10.00	12.79	14.33	10.54	12.35	8.50	13.50	11.02	0.00	9.71
1982	9.34	13.04	14.08	10.72	12.23	9.19	13.64	11.12	0.00	9.91
1983	10.26	12.96	14.09	10.70	13.23	8.60	13.60	11.18	0.00	10.70
1984	10.37	13.29	14.01	10.59	13.16	9.23	13.67	11.20	0.00	9.88
1985	10.87	13.32	14.17	11.14	12.96	9.30	14.03	11.31	7.79	10.22
1986	9.91	13.22	14.06	10.65	12.82	9.21	13.78	11.14	9.90	9.77
1987	10.14	13.18	14.43	10.88	12.71	9.52	13.88	11.24	11.04	9.72
1988	9.86	13.23	13.97	10.79	13.68	9.23	13.82	11.01	11.45	9.69
1989	9.39	12.89	14.19	11.10	13.14	9.34	13.82	11.36	11.85	9.24
1990	10.01	13.19	14.35	10.82	13.39	9.13	13.88	11.44	12.10	9.28
1991	10.59	12.98	14.23	10.75	12.93	9.62	13.91	11.25	12.24	9.55
1992	10.57	13.42	14.74	10.10	13.35	9.92	13.97	11.26	12.32	10.32
1993	10.38	13.28	14.92	11.40	13.02	9.52	14.21	11.27	12.41	9.53

Table 2. σ for the same 10 journals, 1980-1993

The statistic σ seems to have the desirable qualities of taking into account both citations and impact factor, but "smoothing" the annual variations in the impact factor. The annual ranking it provides for the 10 plant science journals we studied seems to us to accord with our impressions of these journals. We have also calculated σ for 3 genetics journals (*Mutation Research* , *Environmental & Molecular Mutagenesis* and *Mutagenesis*); indications are that σ provides an annual ranking that accords well with expert opinion of the status of these journals. Plainly σ needs to be tested against user perceptions of the standing of journals in a number of academic areas, over extended time periods.

5. SIZE DISTRIBUTIONS

The data of Hill & Murphy[5] indicates a power law relationship between the statistic: "the number of Australian authored articles in a journal", and rank by this statistic. A more detailed analysis using SCI data from 1991, including even those SCI source journals with 1 or more Australian-authored articles, reveals a somewhat different picture. First, the log-log plot of the distribution of Australian-authored articles by journal rank has a relatively non-linear tail corresponding to those journals with approximately 8 or less Australian-authored articles. For each $N \geq 0$ we removed those journals with less than N Australian-authored articles and succesively calculated a simple regression line. This gives an r^2, slope of the corresponding regression line, and vertical intercept that vary with N as follows:

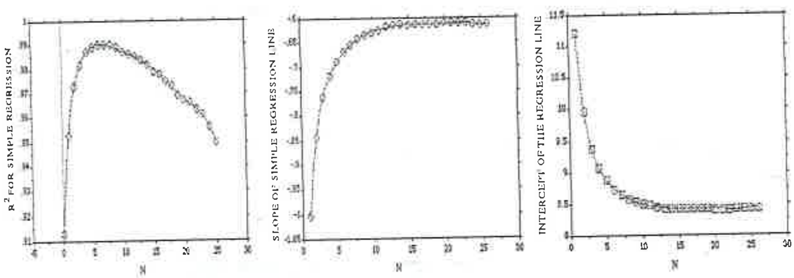

Figure 6.

The plateauing of the latter two graphs around $N = 8$, and the high r^2 for $N = 8$ (namely, the maximum r^2 of 0.990), indicate that so far as the linear part of the log-log distribution is concerned, Hill & Murphy made a sound choice in ignoring journals with less than 10 Australian-authored articles. We estimate the slope as lying between -0.612 and -0.634.In other words, for 1991 the number $j(r)$ of Australian-authored articles in a journal of rank r approximately satisfies a power law relation: $j(r) \approx \frac{234}{r^D}$ where D is approximately 0.62. This tells us that the size distribution of Australian authored articles - the distribution of the number $AUS(n)$ of journals with n or more Australian authored articles, as a function of n - also satisfies a power law. Rather than obtaining this distribution theoretically from a smooth approximation to discrete data (see van Raan[19], for example) we determine the size distribution directly from 1990 through 1993, are as follows:

	Aus	*Neth*	*China*	*S.Korea*	*Sweden*	*Switz*
1990	1.47	1.44	1.47	1.75	1.46	1.50
1991	1.47	1.45	1.46	1.76	1.47	1.49
1992	1.45	1.44	1.44	1.64	1.46	1.47
1993	1.44	1.43	1.44	1.61	1.45	1.46

Table 3. Estimates of D for specified countries, 1990-1993

Differing values for the dimension D have an interpretation in terms of the amount of "spread" into the world's scientific journals. A very high value for D indicates a distribution of articles in which almost no journals contain 2 or more articles of that type: in other words, the articles from a country with such a hypothetical distribution are largely spread around so that any given journal contains no more than 1 article from that country. On the other hand a low value for D indicates that there are many more journals with n or more articles from that country, with n reasonably large: this indicates significant "islands" of higher concentrations of that country's articles in particular journals. Naturally, one expects national journals to contain a significant proportion of articles from that country. However a lower value of D indicates the existence of many journals with a significant number of articles from a given country.

With the exception of South Korea and Switzerland the dimension estimates are remarkably consistent across countries and years. Even Switzerland's decrease from 1.50 in 1990 to 1.46 in 1993 is close to the other dimension estimates.

The extended estimates of D for Australia for the period 1982-1993 also show a marked lack of variability:

82	83	84	85	86	87	88	89	90	91	92	93
1.47	1.45	1.47	1.46	1.46	1.47	1.47	1.47	1.47	1.47	1.45	1.44

Table 4. Estimates of D for Australia, 1982-1993

The dimensions of the annual size distributions seems therefore not to be directly related to either citation share or publication share. Rather, dimension is an additional factor that indicates the degree to which a country's publications "spread" into journal space. We hypothesise that South Korea's size distribution dimension will stabilize around 1.45 within a few years.

6. A MODEL FOR FRACTAL DISTRIBUTION OF SCIENCE PUBLISHING

Many bibliometric data sets are reasonably described by power laws over a large part of their range. This leads us to suspect that there are dynamic processes at work, producing fractal distributions. Sometimes, distributions that are observed to reasonably fit a power law decay have behind them a theory that lends convincing support to the observations, and sometimes they do not. A good example of the former is the distribution of rivers in their deltas . An example where there presently is no known theory is the size distribution of moon craters (Takayasu[28], pp. 34-36).

We argue here that size distributions of science journal publishing are more akin to the former example than to the latter. What we propose is a general principle, with (as yet) no detailed mathematical arguments, to shed some light on the frequent occurence of fractal size distributions in science journal publishing.

The general model we have in mind is described as follows. There is a potentially infinite collection of *individuals* (corresponding to articles written for publication) of a finite number of *types* (corresponding to the field of science to which the article belongs),and a finite number of *sites* for each type (corresponding to the different journals in a given field). The individuals *attach* themselves to a particular site (corresponding to submission for publication) and, in a given time frame, may be *permanently attached* to that site (corresponding to acceptance for publication by a given journal), or *rejected* from the site (corresponding to rejection for publication). A rejected individual has a limited *life* during which it may attempt to attach to other sites. Several rejections usually leads to the demise of an individual (correfrom the data. A plot of $log_2(AUS(n))$ versus $log_2(n)$ is approximated by a linear function over a large range:

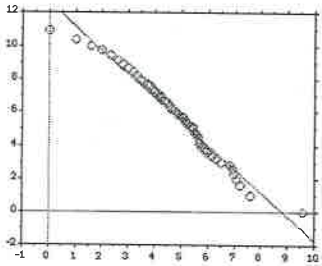

Figure 7. $log_2(AUS(n))$ versus $log_2(n)$; $r^2 \approx 0.968$

By analogy with other power law distributions (see Takayasu, pp.18-19, for example) we refer to the slope D of this log-log plot as the *dimension* of the distribution.

5.1 Maximum likelihood estimation of dimension

Pao[20], Nicholls[21,22,23] and Rousseau[24] recommend using a maximum likelihood estimator to estimate a value for the dimension D when a law such as $f(x) = Kx^D$, with $D \geq 1$, is suspected (see also Johnson and Kotz[25], pp.240-244. The estimate is obtained by evaluating $\frac{\sum f(x) log(x)}{\sum f(x)}$ from the data and then finding D so that $-\frac{dlog(\zeta(D))}{d(D)} = -\frac{\zeta'(D)}{\zeta(D)} = \frac{\sum f(x) log(x)}{\sum f(x)}$, where $\zeta(s)$ is Riemann's zeta function ($= \sum_{n \geq 1} \frac{1}{n^s}$ for $s > 1$), and "log" is the natural logarithm. Rousseau[24] provides a refinement of the tables in Johnson and Kotz[25] (taken originally from Walther[26]). A good approximation to D can be found easily using $Mathematica^{TM}$ which has a built-in zeta function (Wolfram[27], p.574). $Mathematica^{TM}$ 2.2 does not algebraically calculate the derivative of the zeta function, but a decent approximation can be obtained by setting $\frac{d\zeta(x)}{dx} = \frac{\zeta(x+\epsilon)-\zeta(x)}{\epsilon}$ where ϵ is small - say $\epsilon = 10^{-6}$. Then $Mathematica^{TM}$'s built-in secant routine for numerically solving equations (using the function FindRoot[ ] with two starting values: see Wolfram[27], p.96) gives a good numerical approximation to D.

5.2 Comparison with other countries

We begin with a hypothesis, that appears from linear regression to be eminently reasonable. It is that for a country, C, the number of journals with n or more articles written by authors from the country C, is approximately $\frac{A}{n^D}$ where A and D are positive constants, with $D > 1$. Under this hypothesis we have determined D using a maximum likelihood estimate for the countries *Australia, Netherlands, People's Republic of China, South Korea, Sweden* and *Switzerland* from 1990 through 1993, with the Australian data extended back to 1982.

There are a number of reasons we have used these countries with which to compare Australia over the period 1990-1993. Bourke & Butler[1] (p. 49) examined the relationship between Australia's declining citation share in conjunction with a constant publication share for a number of countries. Of the countries they studied only Australia and Sweden had a relatively constant publication share and a declining citation share. By contrast, France and Switzerland showed a constant publication share and rising citation share, and Canada, West Germany, Japan, Netherlands, China and South Korea all showed both a rising publication share and citation share. South Korea and China are "new" countries in this system and have improved their shares markedly from a tiny base in the 1980's. The countries that we chose needed to be similar or smaller in output to Australia, due to technical difficulties of manipulating large data sets, and there should be at least one representative from each group. China and South Korea are both "new" countries - China with a fairly constant share from 1990-1993, but South Korea with a nearly doubled output. We examined the differences in size distributions to see if there is a connection between the size distribution parameters and the categorization by citation share/publication share.

The results of these maximum likelihood estimates of size distribution dimension D for these countries sponding to the article no longer being submitted for publication). The sites have a fixed and limited *capacity* for permanent attachment of individuals (corresponding to a fixed number of articles published in a given time period), and in any time period the number of individuals attaching to a given cite is overwhelmingly greater than the capacity of that cite.

In this model we have geometric constraints - the size restriction of a given journal - for a dissipative system, together with processes of injection and aggregation that lead to a state of dynamic equilibrium (this model assumes, as a first approximation, that journals are static cites). Such dynamic equilibria generally give rise to power law distributions (Takayasu[28], p. 116, and Takayasu, Nishikawa & Tasaki[29]; although the exponents in the Takayasu *et al* models lie between $\frac{1}{3}$ and $\frac{1}{2}$).

A *simulation* of a model like this can be obtained by beginning with a number of sites, each specified by a pair (n, p_n) where n is a positive integer less than N (say,$N \approx 3,000$) and $0 < p_n < 1$ for each n, and a number of individuals, a given proportion of which are labelled "0" and the rest labelled "1". We assume that each site has a capacity C independent of the site (say, $C \approx 50$), that individuals attach themselves randomly to a site in the first instance, and that the probability of rejection from site (n, p_n) is p_n. If an individual is rejected by that site then it may attach randomly to a site (k, p_k) with $p_k \leq p_n$. We assume that a given individual can attach to only a fixed number of sites without becoming permanently attached (say 3 sites), and then becomes extinct. We assume a fixed form for the distribution of the p_n by size - say log-normal - and ask: when all sites are full, what is the size distribution of permanently attached individuals labelled "0"? At the present time we are experimenting with simulation models of this nature.

7. REFERENCES

1. P. BOURKE, L. BUTLER, *A Crisis for Australian Science? Performance Indicators Project*, Monograph Series No.1, The Australian National University, Canberra, 1994.

2. SCIENCE WATCH, Australian Science: Some Worries, Mate. 4 (1993) No.9, 1-2.

3. P.ROYLE, A Citation Analysis of Australian Science and Social Science Journals, *Australian Academic and Research Libraries*, 25 (1994) No.3, 162-171.

4. P. ROYLE, R. OVER, The Use of Bibliometric Indicators to Measure the Research Productivity of Australian Academics, *Australian Academic and Research Libraries*, 25 (1994) No. 2, 77-88

5. S. HILL, P. MURPHY, *Quantitative Indicators of Australian Academic Research*, National Board of Employment, Education and Training, Commissioned Report No. 27, Australian Government Publishing Service, Canberra, 1994.

6. S. NARANAN, Power Law Relations in Science Bibliography - a Self-consistent Interpretation, *Journal of Documentation*, 27 (1971) 83-97.

7. S. NARANAN, Power Law Versions of Bradfords Law: Statistical Tests and Methods of Estimation, *Scientometrics*, 17 (1989) Nos.3-4, 211-226.

8. S. D. HAITUN, Stationary Scientometric Distributions. Part I. Different Approximations, *Scientometrics*, 4 (1982) No. 1, 5-25.

9. S. D. HAITUN, Stationary Scientometric Distributions. Part II. Non-Gaussian Nature of Scientific Activities, *Scientometrics*, 4 (1982) No. 2, 89-104

10. B. C. BROOKES, Ranking Techniques and the Empirical Log Law, *Information Processing and Management*, 20, (1984) Nos. 1-2, 37-46.

11. L. EGGHE, On the Classification of the Classical Bibliometric Laws, *Journal of Documentation*, 44, (1988) No. 1, 53-62.

12. L. LEYDESDORFF, The science citation index and the measurement of national performance in terms of scientific publications, *Scientometrics*, 17 (1989) No. 1-2, 111-120.

13. R. TODOROV, W. GLANZEL, Journal Citation Measures: A Concise Review, *Journal of Information Science*, 14 (1988), 47-56.

14. B. B. BENNION, S. KARSCHAMROON, Multivariate Regression Models for Estimating Journal

Usefulness in Physics, *Journal of Documentation*, 40, (1984) No. 3, 217-227.

15. I. N. SENGUPTA, A Weightage Formula to Rerank Periodicals in the Field of Microbiology, *Scientometrics*, 17 (1989) Nos. 3-4, 289-300.

16. R. DEURENBERG, Journal Delselection in a Medical University Library by Ranking Periodicals Based on Multiple Factors, *Bulletin of the Medical Library Association*, 81, (1993) No. 3, 316-319.

17. P. O. SEGLEN, The Skewness of Science, *Journal of the American Society for Information Science*, 43 (1992) No. 9, 628-638.

18. E. GARFIELD, *Essays of an Information Scientist*, Volume 4, ISI Press, Philadelphia, 1981

19. A. F. J. VAN RAAN, Fractal geometry of information space as represented by co-citation clustering, *Scientometrics*. 20 (1991) No. 3, 439-449.

20. M. L. PAO, Lotka's Law: A Testing Procedure, *Information Processing and Management*, 21 (1985), 305-320.

21. P. T. NICHOLLS, Empirical Validation of Lotka's Law, *Journal of the American Society for Information Science*, 37 (1986) No. 1, 26-33.

22. P. T. NICHOLLS, Estimation of Zipf Parameters, *Journal of the American Society for Information Science*, 38 (1987) No. 6, 443-445.

23. P. T. NICHOLLS, Bibliometric Modeling Processes and the Empirical Validity of Lotka's Law, *Journal of the American Society for Information Science*, 40 (1989) No. 6, 379-385.

24. R. ROUSSEAU, A Table for Estimating the Exponent in Lotka's Law, *Journal of Documentation*, 49 (1993), No. 4, 409-412.

25. N. L. JOHNSON, S. KOTZ, *Discrete Distributions*, Houghton Mifflin, Boston, 1969.

26. A. WALTHER, Anschauliches zur Riemanschen Zetafunktion, *Acta Mathematica*, 48 (1926), 393-400.

27. S. WOLFRAM, *Mathematica. A System for Doing Mathematics by Computer.* Second Edition, Addison Wesley, Redwood City, California, 1991.

28. H. TAKAYASU, *Fractals in the Physical Sciences*, John Wiley and Sons, New York, 1992.

29. H. TAKAYASU, I. NISHIKAWA, H. TASAKI, Power-Law Mass Distribution of Aggregation Systems with Injection, *Physical Review A*, 37 (1988) No. 8, 3110-3117.