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A QUICK AND EASY METHOD TO ESTIMATE THE RANDOM EFFECT ON CITATION MEASURES

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A quick and easy method is presented to estimate the random fluctuations exhibited by citation measures. Applying this method allows for instance a better view on the ranking of journals (their so called "pecking order"), when the ranks are based on the number of recieved citations or on the impact factor of the journal.

Introduction

The *Journal Citation Reports* (*JCR*)[1] volumes of the *Science Citation Index* (*SCI*) and the *Social Science Citation Index* (*SSCI*) annually record, among others, the number of publications, the impact factor and the immediacy index of the journals in the ISI database. The impact factor of a journal in a fixed year is defined by *Garfield*[2] as the number of citations in that year to papers published in the two preceeding years divided by the number of papers published in that journal during these two years.

The data of the *JCR* have shown their importance in several domains, such as the building of collections, the estimation of the importance of scientific publications (for instance for potential sponsors), or the choice of the most appropriate (most prestigious?) journal by a prospective author. All these applications imply a ranking of journals according to their "importance". How sensible such an approach is, has been amply discussed.[3,4]

In this paper we will consider the following problem concerning citation measures. The numbers given in the *JCR* fluctuate over the years: which part of these fluctuations is only a random effect and does not reflect a real rise or drop? Moreover, how can one estimate this effect without having to conduct a longitudinal study over several years?

The approach we propose is simpler than the one by *Schubert* and *Glänzel,*[5] but gives only a lower bound on the size of the fluctuations, while their method aims at a more precise estimate of the standard deviation of the impact factor.

The main results of this paper have been announced by *Nieuwenhuysen* at the "NFWO Bibliometrics Day", Antwerp, 17 April, 1986.[6]

A lower bound on the random effect on citation measures

In a similar way as in Ref.[5] we consider the publication of papers during the period (s_1, s_2) as actions, and citations to these papers in an arbitrary year $t \geqslant s_2$ as reactions. Citations can be considered as random events and the whole action-reaction system can be modelled in the framework of a discrete stochastic process. For every $n \in N$ we denote by X_n the stochastic variable which maps a paper published in a fixed journal during the period (s_1, s_2) to the number of citations it receives in the nth year after s_2.

We want to study the random effect on the number of citations only, making no allowance for variations in quality or other more deterministic influences. Therefore, we will use as a first approximation that X_n has a Poisson distribution with mean equal to the observed frequency of citations in the nth year after s_2. With regard to the fluctuations we want to observe, this approximation is a rather conservative one. Indeed, here we do not take into account the variance on X_n which is due to differences among the papers published in the same journal, or which is due to differences in the journals where the papers are cited.

Under the Poisson model, the variance is equal to the mean. When the mean is large, the Poisson distribution is approximately normal (cf Ref.[7], p. 78). Thus we can compute crude confidence intervals for the number of citations. If CIT denotes the observed number of citations in a fixed year, a 95% confidence interval is given by

$$[\mathrm{CIT} - 1.96\ (\mathrm{CIT})^{1/2},\quad \mathrm{CIT} + 1.96\ (\mathrm{CIT})^{1/2}]$$

and a 99% confidence interval is given by:

$$[\mathrm{CIT} - 2.57\ (\mathrm{CIT})^{1/2},\quad \mathrm{CIT} + 2.57\ (\mathrm{CIT})^{1/2}].$$

When considering the impact factor as defined by *Garfield,*[2] the interval $[s_1, s_2]$ takes the form $[s, s + 1]$ and we only need X_1. If we denote the number of articles published in a fixed journal during the period $[s, s+1]$ by A, then the impact factor is

$$\mathrm{IMP} = X_1/A.$$

Then the 95% and the 99% confidence intervals for the impact factor of a journal are:

$$\left[\mathrm{IMP} - 1.96\,\frac{(\mathrm{CIT})^{1/2}}{A}, \quad \mathrm{IMP} + 1.96\,\frac{(\mathrm{CIT})^{1/2}}{A}\right]$$

and

$$\left[\mathrm{IMP} - 2.57\,\frac{(\mathrm{CIT})^{1/2}}{A}, \quad \mathrm{IMP} + 2.57\,\frac{(\mathrm{CIT})^{1/2}}{A}\right].$$

This again is a very conservative estimate for a confidence interval of IMP because all random variation on the number of publications is ignored.

This is illustrated in Table 1 and Fig. 1 for one journal.

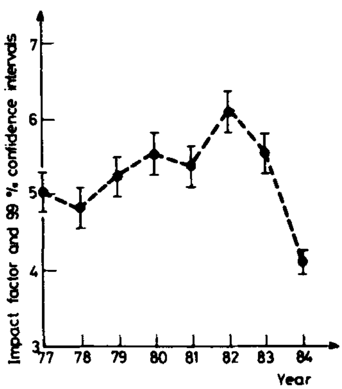

Fig. 1. Impact factors and 99% confidence intervals for the *American Journal of Cardiology*

Table 1
American Journal of Cardiology: 99% confidence intervals for the impact factors in the period 1977–1984

Year	99% confidence interval	Year	99% confidence interval
1977	(4.80, 5.30)	1981	(5.16, 5.63)
1978	(4.63, 5.11)	1982	(5.85, 6.37)
1979	(5.02, 5.51)	1983	(5.35, 5.78)
1980	(5.30, 5.78)	1984	(3.97, 4.28)

As observed in Ref.[8] (where a similar reasoning has been used) the net effect of the two conservative assumptions made, is that the estimated confidence intervals for IMP are likely to exaggerate the statistical significance of any rise or decline of an observed impact factor to outside the confidence interval.

In a similar way we can form confidence intervals for the immediacy index (IMM). Here the interval $[s_1, s_2]$ becomes $[s, s] = \{s\}$ and we use the stochastic variable X_0. If A_0 denotes the number of publications in a fixed journal during the year s, then IMM $= X_0/A_0$.

Confidence intervals are given by:

$$\left[\text{IMM} - 1.96\,\frac{(\text{CIT})^{1/2}}{A_0},\quad \text{IMM} + 1.96\,\frac{(\text{CIT})^{1/2}}{A_0}\right] \quad \text{(95\% confidence interval)}$$

$$\left[\text{IMM} - 2.57\,\frac{(\text{CIT})^{1/2}}{A_0},\quad \text{IMM} + 2.57\,\frac{(\text{CIT})^{1/2}}{A_0}\right] \quad \text{(99\% confidence interval).}$$

A test for the Poisson model

Under the Poisson model discussed above the coefficient of variation (standard deviation divided by the mean) for the stochastic variable X_n takes a particularly simple form: it is equal to $(\text{CIT})^{-1/2}$ (in a fixed year). As a crude test we have picked at random thirty journals from the *JCR* of the *SCI*, edition 1977, and have calculated their coefficient of variation for the number of citations over the period 1977–1984. To choose these journals we used a table of random numbers. Moreover, we took only those journals which were still included in the 1984 edition of the *JCR* and which received at least 10 citations in 1977. Indeed, it makes little sense to do a citation analysis on journals that are hardly cited.

Comparing these coefficients of variation with the inverse of the square root from the observed number of citations in 1984 we expect the former numbers to be larger than the latter, as $[\text{CIT (1984)}]^{-1/2}$ takes only the random effect in one year into account.

A similar test has been done for the impact factor. Here again the coefficient of variation can be approximated (lower bound) by $[\text{CIT (1984)}]^{-1/2}$ as the standard deviation is approximated by $(\text{CIT})^{1/2}$ divided by the number of publications in 1982–1983 and the mean by the observed impact factor, which equals the number of citations in 1984 divided by the number of publications in 1982–1983.

Table 2
A: journal, abbreviated as in the *JCR*;
B: coefficient of variation on the number of citations in 1977–1984;
C: coefficient of variation on the impact factor in 1977–1984;
D: $[(\mathrm{CIT}\ (1984)]^{-1/2}$

	A	B	C	D
1	ACCOUNTS CHEM RE	0.109	0.064	0.033
2	AM J CARD	0.207	0.111	0.015
3	B AM METEOROL SCI	0.346	0.338	0.086
4	BELL SYST TECHN J	0.157	0.254	0.074
5	BIOL REV	0.194	0.226	0.101
6	BRIT HEART J	0.033	0.062	0.034
7	CAN J NEUROL SCI	0.402	0.379	0.096
8	CELL TISSUE RES	0.071	0.045	0.027
9	CHEM BRIT	0.214	0.184	0.101
10	DEEP SEA RES	0.268	0.222	0.059
11	DOKL ACAD NAUK BSSR	0.126	0.138	0.095
12	ECON GEOL	0.236	0.208	0.055
13	ERGONOMICS	0.226	0.210	0.128
14	FOREST SCI	0.392	0.311	0.093
15	HAEMOSTASIS	0.332	0.316	0.073
16	IEEE T POWER AP SYS	0.422	0.132	0.049
17	J ELASTICITY	0.146	0.189	0.192
18	J EXP ZOOL	0.077	0.097	0.039
19	MATH ANNAL	0.158	0.195	0.069
20	METABOLISM	0.150	0.161	0.035
21	METROLOGIA	0.405	0.286	0.186
22	NUTR REV	0.298	0.298	0.107
23	POWDER TECHNOL	0.108	0.123	0.092
24	PROG BIOPHYS MOL BIO	0.396	0.285	0.074
25	PSYCHOPHAR	0.295	0.109	0.035
26	SCI AM	0.073	0.071	0.039
27	SCOT MED J	0.325	0.337	0.160
28	ULTRAMICROSCOPY	0.560	0.313	0.053
29	WEED SCI	0.109	0.101	0.068
30	X-RAY SPECTROM	0.329	0.327	0.167

As seen from Fig. 2 and Fig. 3, which have been derived from Table 2, the results confirm that $(\mathrm{CIT})^{-1/2}$ is a lower bound for both coefficients of variation: all but one exceptional point lie above the first bissectrice of the diagram. Remark also that 2 times in 3 the variation coefficient on citations is larger than the variation coefficient on the impact factor.

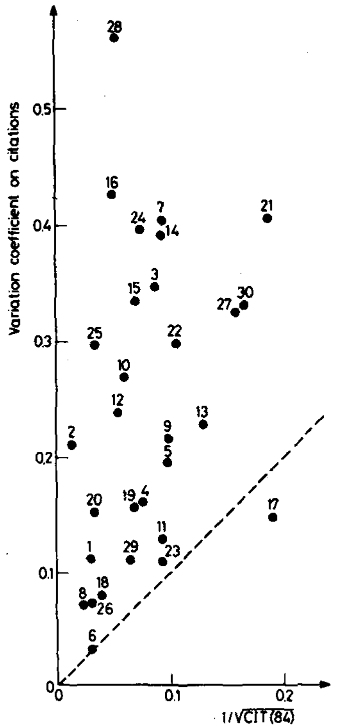

Fig. 2. Variation coefficient on citation vs $[\text{CIT}(1984)]^{-1/2}$

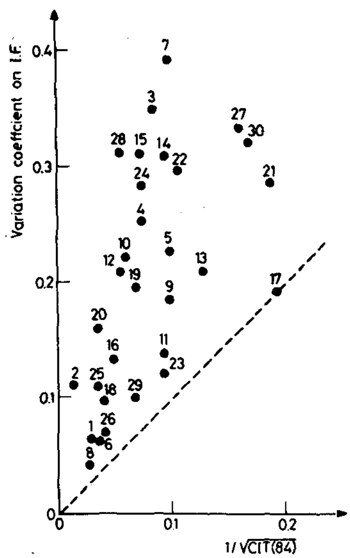

Fig. 3. Variation coefficient on impact factor vs $[\text{CIT}(1984)]^{-1/2}$

Implications on the "pecking" order of journals

Bibliometric indicators such as the impact factor provide a *ranking of scientific* journals, which can be thought of as a ranking according to influence (of Ref.[9]). As such, this ranking could be used for instance to help a librarian in his acquisition strategy (see the Introduction). Upper and lower bounds for the rank based on the impact factor or the immediacy index can easily be obtained by using the model presented in the preceeding sections. This should be taken into consideration when decisions are made based on these indicators.

Let us look at two examples. The 1984 impact factor of the *Journal of Cardiology* was 4.127; this puts it at the 120th place of all journals in the *SCI.* Using a 95% confidence interval according to the simple Poisson model, places it between the 116th and the 123rd position. So for such a journal with a relatively high impact factor, only a small shift should be expected from year to year. However, for journals with a lower impact factor, this shift can be much greater. For instance, the 1984 impact factor of the *Doklady Nauk SSSR* was 0.381; this gave it the 2472nd place. A 95% confidence interval places it between the 2428th and the 2527th position, which means a shift of 50 places in both directions.

A comparison with the approach of Schubert and Glänzel

In their paper[5] on comparisons based on the citation impact, *Schubert* and *Glänzel* use a negative binomial distribution to describe the citation process. Their model gives a better description of the real situation than the Poisson model (as shown by the tests they have conducted and by the use of this distribution in similar situations[10]). However, our approach is much simpler than theirs as we do not have problems with the estimation of parameters of the distribution. To estimate one of the two parameters of the negative binomial distribution they moreover have to know the fraction of uncited papers. Even then a computer program is needed to finish the job.

Our method, on the other hand, only gives a lower bound on the size of the random effect, but can be done with the *JCR* data and a hand-held calculator.

A direct comparison between the two results is difficult as the *Schubert-Glänzel* impact factor has been corrected: only articles, reviews, notes and letters to the editor are taken into account. Moreover, they have used the *SCI* Corporate Tapes from 1978 and 1979. This should yield the 1980 impact factor but a comparison with the 1980 data as given by the *JCR* shows that this can not be entirely correct. Anyhow, we have used the 1980 results to compare our calculations with those obtained by *Schubert* and *Glänzel.* From the first 100 journals given in the 1980 edition of the *JCR* 81 also appear in the *Appendix* of Ref.[5]. From these 81 journals we found that the standard deviation on the impact factor as calculated by our method was smaller than the standard deviation given by *Schubert* and *Glänzel* in 70 out of 81 cases (i.e. in 86% of the cases). In most of the situations where their standard deviation is smaller than ours there seems to be an error involved. For instance: the *JCR* (1980) says that the journal "ACAROLOGIA" was cited 11 times and had 109 source publications, while the *Schubert-Glänzel* paper gives only 50 publications which were cited only 2 times (corrected impact factor: 0.039).

We also compared the intervals "Impact factor ± one standard deviation" to see whether the two intervals overlapped. This was the case in 64 out of 81 cases (79%).

Conclusion

The use of the Poisson model gives a useful, quick and easy method to obtain a lower bound on the fluctuations of citation measures.

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