Information Processing & Management Vol 22, No 2, pp. 251–258, 1986
Printed in Great Britain.

0306–4573/86 $3.00 + .00

A STATISTICAL ASSESSMENT OF TWO MEASURES OF CITATION: THE IMPACT FACTOR AND THE IMMEDIACY INDEX

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(*Received* 6 *June* 1985; *in revised form* 21 *Oct.* 1985)

Abstract—The dynamics and internal structure of the system of scientific communication are greatly influenced by the varying quality of the primary journals in which scientific information is published. The analysis of citations is among the means by which policy-makers, scientists and librarians seek to achieve a greater understanding of the qualitative forces that affect formal communications in science. This paper reports the findings of an investigation which was conducted in order to determine if either the impact factor or the immediacy index—two derivative measures of citation formulated by Garfield and the Institute for Scientific Information—provide useful insights into the qualitative relations among scientific journals. The results of the investigation, which was concerned with the statistical characteristics of the relationships among the variables forming the basis for the two measures, indicate that the measures are not significant and that the order which either produces among a list of journals is not markedly different than that which is produced when such journals are ranked in terms of uncorrected rates of citation.

INTRODUCTION

Eugene Garfield, probably the world's foremost proponent of citation analysis, believes that the study of bibliographic citations "provides a number of interesting and useful insights into the network of journals that function as the primary, formal communications medium of science."[1] According to Garfield, there are five different measures of citation which may be utilized in order to describe how information is transmitted through the scientific literature and evaluate the constituent parts of this system of formal communication. Two of these measures, the impact factor and the immediacy index, are the product of efforts by Garfield and the Institute for Scientific Information (ISI) to develop quantitative expressions that are reliably indicative of the relative importance of journals within the framework of scientific communication. The purpose of this paper is to report the results of an investigation which was conducted in order to determine if either of the measures is significant.

BACKGROUND

Both the impact factor and the immediacy index are ratios. The basis for the derivation of each measure is the citation rate (that is, the number of times a journal was cited), divided by the citation potential (the number of citable articles which the journal published). The impact factor is the ratio of the number of citations which a journal receives in the course of a given year to the number of citable articles published by that journal within the two preceding calendar years, whereas the immediacy index is the ratio of the number of citations which a journal receives in its most recent complete year of publication to the number of source items published by that journal during the same interval.

The purpose of the impact factor is to offset the advantage in potential for citation that larger journals which publish more material supposedly have over smaller journals which publish relatively fewer articles. The immediacy index, which is regarded as an

indicator of how rapidly a journal's material is picked up and used, is likewise intended to discount the putative statistical advantage which accrues to the journals which publish greater number of articles[2].

Correcting rates of citation on this basis is thought to produce measures which are more precisely indicative of a journal's qualitative effect upon formal communications in science than are measures predicated exclusively upon the enumeration of citations. For example, journals which publish only a few papers each year, but which publish papers that receive citations in disproportionately high numbers, are more readily identified by means of such corrections and what Garfield contends is their true qualitative impact, is revealed. Such corrections in the rate of citations are also thought to facilitate the identification of journals whose high rates of citation are largely a function of their greatest size, rather than their greater quality.

It is important to note that the conceptual basis upon which the two measures rest is very limited, excluding a number of other variables which bibliometricians view as potentially significant factors in determining the rates at which journals are cited. The average length of the citable article, thought by Narin to be a significant variable in light of the fact that the journals which tend to publish longer review articles also tend to have higher impact factors, is not taken into account[3]. Nor does this method of correcting rates of citation permit potentially important distinctions in regard to the nature and/or merits of the citing journals, some of which are surely more important than others, some of which may be journals from fields in which patterns of publication and citation are so distinctive as to preclude their valid incorporation in more general comparisons[4]. Another significant limitation (of these and other measures predicated upon rates of citation) is that the exposure of the citable articles is not taken into account, although it is not unreasonable to imagine that the rates at which journals are cited are influenced to a significant degree by the extent to which their contents are disseminated.

Another factor which suggests caution in the utilization of the two measures as evaluative instruments is the absence of data in the published record which corroborate the contention that the impact factor and the immediacy index are more informative and more meaningful than the uncorrected rates of citation upon which each is based. To determine if either measure provides genuinely more useful insights into the qualitative structure of journal-based communications in science, an investigation was conducted in order to ascertain and examine the basic statistical characteristics of the relationships underlying the impact factor and the immediacy index. Since Garfield's notions about the two measures are apparently based upon the presumption of a significant but not clearly defined relationship between potential for citation and rates of citation, the investigation was focused primarily upon an examination of the relationship between citable articles and citations to those articles and also upon the comparative effects of the impact factor and the immediacy index as instruments of ranking[5].

EXPERIMENTAL METHODS

The investigation from which the findings of this paper are derived are based upon an examination of 240 journals. The journals were selected at random from an alphabetical list of the 3855 journals which were indexed by *Science Citation Index* in 1980. The number of journals in the sample was established upon the basis of computations which suggested that a set representing 5–6 percent of the journals indexed by *Science Citation Index* would be indicative and sufficient. The investigation was concerned with reported patterns of publication and citation for 1978–1980; the consideration of patterns for this period is not intended to suggest that the interval was typical or atypical. All pertinent information was extracted from ISI's *Journal Citation Reports* for 1980. The following data were collected for each of the titles in the sample: (1) number of citations in 1980 to papers published in all years; (2) number of citations in 1980 for papers published in each year between 1978–1980; (3) number of citable articles pub-

lished in each year between 1978–1980; (4) the impact factor for 1980; and (5) the immediacy index for the same year.

Two general relationships were examined, the first of which was that between rates of citation and potential for citation. In order to measure this first relationship, the Pearson product/moment coefficient of correlation was computed.

The second general relationship under consideration was that which was effected by ranking titles in the sample in terms of uncorrected rates of citation (that is, citations in 1980 to all years, and citation in 1980 to papers published in 1978–1980), impact factors and immediacy indices. The statistical relationships among lists so ordered were measured through the computation of the Spearman rank/order coefficient of correlation, the coefficient being "a distribution-free test statistic for the independence problem that assigns greater weights to those (X, Y) pairs differing more in the respective rankings of X and Y observations."[6] Since neither the number nor the proportion of tied observations was large, the effect of such ties upon the Spearman coefficient was judged to be negligible[7].The relationships were examined in their various aspects in order to determine the extent to which the utilization of the impact factor and/or the immediacy index affects the order to lists of journals ranked upon the basis of uncorrected rates of citation, this being the means by which to assess the purportedly greater qualitative insight of the two measures within the larger context of the scientific journals encompassed by *Science Citation Index*.

EXPERIMENTAL RESULTS

Within the framework of the two general relationships, a series of more specific relationships were examined. The first such relationship to be considered was that between the variable forming the basis for the impact factor. Entailing the correlation of the number of citations which the journals in the sample set received in 1980 to the number of citable articles which the journals published in 1978–1979, the computation of the Pearson coefficient—the Pearson r—produced a result of +.879.

The second specific relationship which was considered was that between the variables forming the basis for the immediacy index, involving the correlation of the number of citations which the journals received in 1980 to the number of citable source items published within the same interval. The Pearson r produced as the result of this computation was +.916.

The third specific relationship under examination was that between a list of the journal titles in the sample ordered according to uncorrected rates of citation for 1980 in reference to papers published in all years and a list of the same titles ordered upon the basis of the obtaining impact factors for 1980. The computation according to Spearman's formula produced a correlation coefficient, the Spearman rs, of .783. The relationship between a list of the journals in the sample ordered according to uncorrected rates of citation for 1980 in reference to papers published in all years and a list of the same titles ordered upon the basis of their immediacy indices for 1980, revealed a similar degree of correlation, producing a Spearman rs of .840.

The fourth specific relationship to be considered was that between a list of the journal titles ordered according to uncorrected rates of citation for 1980 in reference to papers which had been published in 1978–1979 and a list of the same titles ordered upon the basis of their respective impact factors. The result of this comparison, which was computed in terms of the Spearman rs, was a coefficient of correlation of .808.

The fifth specific relationship under scrutiny was that between a list of the journal titles in the sample set ordered according to uncorrected rates of citation for 1980 in reference to citable papers published during the same year and a list of the same titles ordered in terms of their immediacy indices. The resultant coefficient was .819.

The results of a further examination of the relationships among the aforementioned factors and variables corroborated these findings. It was determined that the relationship between uncorrected rates of citation for 1980 in reference to papers published in

1978–1979 and corrected rates expressed as impact factors was very close, producing a Pearson *r* of +.967. It was also determined that the relationship between uncorrected rates of citation for 1980 in reference to papers published in that year and corrected rates expressed as immediacy indices was even closer, producing a Pearson coefficient of +.998[5].

A comparison of lists ranked according to the impact factors and the immediacy indices indicated once again that the obtaining relationship was one of considerable statistical strength, producing a Spearman *rs* of .7341. In this and all other cases, the products of the computations were subjected to a standard test for statistical significance—the test whose outcome is predicated upon critical values of *t* in relation to the pertinent degrees of freedom—the administration of which indicated that all but one of the relationships under examination were statistically significant, ranging in levels of significance from .001 to .02. Only in a comparison of rank by uncorrected rates of citation in 1980 to papers published in that year to rank by immediacy indices was a relationship of a non-significant nature established, producing a Spearman coefficient of .332.

The results indicate that the relationship between rates of citation and potential for citation is generally very strong and especially so in regard to the more specific relationship between the number of citations received in the most recent complete year of publication and the number of source items published within that same period. Such high degrees of correlation constitute impressive evidence to support the notion that journals which publish larger number of papers do indeed tend generally to be cited more often than the journals which publish papers in lesser numbers, but the statistical strength of the associations also suggests that correcting rates of citation in terms of the number of citable papers published in the obtaining period does not generally or effectively discount the advantage in potential for citation which larger journals hold over smaller journals, since the magnitude of the pertinent Pearson coefficients indicates that within the scope of publication defined by the coverage of the *Science Citation Index* the relationship between rates of citation and numbers of citable articles is very close.

The magnitude of the Spearman coefficients indicates that the utilization of the impact factor or the immediacy index does not produce rank/order lists which are generally or significantly different from those produced upon the basis of uncorrected rates of citation, either in reference to paper published in specific years or papers published in all years. The lists of journals ranked according to these various measures of citation do differ, but the coincidence of rank and order is so great as to indicate that the effect of either measure upon the qualitative ranking of larger numbers of journals is statistically insignificant.

A comparative examination (see Tables I–V) does indicate that the impact factor and the immediacy index do produce noteworthy alterations in rank and order specific to the uppermost portions of lists so configured. For example, the journal in the sample set which received the greatest number of citations in 1980 to papers published in all years and papers published in 1978–1979, *Biochimica et Biophysica Acta*, ranked only 18th in terms of the impact factor, whereas the publication in the sample which was assigned the highest impact factor, *Advances in Immunology*, ranked only 35th in terms of citations to papers published in all years. *Advances in Immunology* failed to elicit enough references in 1980 to papers published during 1978–1979 to rank among the first 50 journals in the sample in terms of uncorrected rates of citation for the obtaining periods.

Of the 24 publications in the sample receiving the greatest number of citations in 1980 to papers published in all years, four journals were cited more than 11,000 times, and 22 journals were cited more than 3,000 times. Of the 24 publications in the sample bearing the highest impact factors, only 11 received more than 3,000 citations to papers published in all years and only 10 journals received more than 500 citations to papers published in 1978–1979. On the scale employed by the Institute for Scientific Information, a publication entitled *Advances in Protein Chemistry*, which received a total

Table I. Top twenty-four journals ranked by citations in 1980 to papers published in all years [sample].

Journal titles*	Citations	Impact factor
Biochim Biophys Acta	67,641	2.864
J Phys Chem—US	20,432	2.161
J Organomet Chem	13,475	2.627
Nuc Phys A	11,801	2.103
Infect Immun	9,864	2.667
J Neurophysiol	7,652	4.158
J Catal	6,383	2.746
Cold Spring Harbor Sym	5,808	4.770
J Med Chem	5,278	1.728
Ann Phys—New York	5,132	2.902
Metabolism	5,027	3.325
Brit J Surg	4,859	1.382
Cell Tissue Res	4,823	1.802
Prog Theor Phys	4,738	1.331
J Invest Dermatol	4,590	2.814
Am Nat	4,494	2.815
J Theor Biol	3,513	1.336
Immunochemistry	3,365	2.897
Naturwissenschaften	3,353	0.961
Mar Biol	3,296	1.681
Agron J	3,133	0.641
Izv An SSSR Khim	3,111	0.498
Thromb Res	2,984	2.022
J Polym Sci	2,867	—

* Title abbreviations are those employed by the Institute for Scientific Information and *Science Citation Index*.

of 58 citations in 1980 to the eight papers which it published during 1978–1979, ranked substantially higher in terms of the impact factor than *Biochimica et Biophysica Acta*, which published 4210 papers during 1978–1979 that were cited a total of 12,056 times in 1980. In terms of citations in 1980 to papers published in all years, *Advances in Protein Chemistry* received a total of 1,312 references, whereas *Biochimica et Biophysica Acta* received a total of 67,641 citations.

Table II. Top twenty-four journals ranked by citations in 1980 to papers published in 1978–1979

Journal titles	Citations	Impact factor
Biochim Biophys Acta	12,056	2.864
J Organomet Chem	4,556	2.627
Infect Immun	3,275	2.667
J Phys Chem—US	2,571	2.161
Nuc Phys A	2,486	2.103
Cell Tissue Res	1,512	1.802
Cold Spring Harbor Sym	1,388	4.770
J Catal	1,373	2.746
Metabolism	1,310	3.325
J Med Chem	1,035	1.728
Thromb Res	1,031	2.022
Prog Theor Phys	986	1.331
J Neurophysiol	919	4.158
J Invest Dermatol	892	2.814
Z Phys A Atoms Nucl	892	1.535
Mar Biol	763	1.681
Ann Phys—New York	711	2.902
IEEE T Nuc Sci	687	0.506
Brit J Surg	647	1.382
Izv An SSSR Khim	639	0.498
J Theor Biol	608	1.336
Am Nat	594	2.815
J Assoc Off Ana Chem	499	0.854
Ann Rev Physiol	490	7.424

Table III. Top twenty-four journals ranked by the impact factor for 1980 [sample].

Journal titles	Impact factor	Citations
Adv Immunol	28.556	257
Ann Rev Biophys Bio	8.667	312
Ann Rev Physiol	7.424	490
Adv Protein Chem	7.250	58
Semin Hematol	7.159	315
Method Membrane Biol	5.375	43
Struct Bond	5.125	82
Cold Spring Harbor Sym	4.770	1,388
Prog Nucl Mag Res Sp	4.769	62
Crc Crit R Biochem	4.710	146
J Neurophysiol	4.158	919
Hypertension	3.600	306
Metabolism	3.325	1,310
Syst Zool	3.297	211
Ann Phys—New York	2.902	711
Immunochemistry	2.897	394
Biochim Biophys Acta	2.864	12,056
Am Nat	2.815	594
J Invest Dermat	2.814	892
J Catal	2.746	1,373
Riv Nuovo Cimento	2.731	71
Coordin Chem Rev	2.729	131
Infect Immun	2.667	3,275
J Organomet Chem	2.627	4,556

Publications such as *Advances in Immunology* and *Advances in Protein Chemistry* are undoubtedly important journals within their respective fields. However, even when examined on a basis independent of the statistical findings introduced above, it does not seem wholly reasonable to suggest that the impact of *Biochimica et Biophysica Acta* is less than that of *Advances in Immunology* or *Advances in Protein Chemistry*, given that this first journal was cited in 1980 at a rate that was 32 times higher than that of the second journal and 51 times higher than that of the third journal. Yet, that is one qualitative suggestion which may be derived from their respective impact factors.

Table IV. Top twenty-four journals ranked by citations in 1980 to papers published in 1980 [sample].

Journal title	Citations	Immediacy index
Biochim Biophys Acta	882	0.400
Nucl Phs A	386	0.697
J Organomet Chem	351	0.381
J Phys Chem—US	250	0.360
Infect Immun	209	0.333
Prog Theor Phys	181	0.499
J Neurophysiol	167	0.908
J Med Chem	127	0.444
J Catal	120	0.361
Cell Tissue Res	115	0.293
Kvantovaya Electron	91	0.195
IEEE T Nucl Sci	87	0.291
J Invest Dermatol	87	0.442
Z Phys A Atoms Nucl	82	0.329
Thromb Res	78	0.235
J Theor Biol	65	0.243
Izv An SSR Khim	64	0.332
Cryst Struct Commun	58	0.352
Radio Sci	58	0.513
Philos T Roy Soc A	57	0.274
Brit J Surg	56	0.218
Mar Biol	54	0.300
Am Nat	44	0.328
Hypertension	43	0.358

Table V. Top twenty-four journals ranked by the immediacy index for 1980 [sample].

Journal title	Immediacy index	Citations
Adv Immunol	2.167	13
Semin Hematol	1.182	26
Crc Crit R Biochem	1.071	15
Syst Zool	1.067	16
J Neurophysiol	0.908	167
Carlsberg Res Commun	0.892	33
Nuyc Phys A	0.697	386
J Struct Geol	0.676	23
Ann Rev Physiol	0.643	27
Struct Bond	0.636	7
Arch Int Physiol Bio	0.623	33
J Volcanol Geoth Res	0.581	25
Radio Sci	0.513	58
Ann Phys—New York	0.500	48
Exp Lung Res	0.500	14
Prog Nucl Mag Res Sp	0.500	1
J Immunogenet	0.490	24
Can J Comp Med	0.460	29
RCA Rev	0.458	11
J Med Chem	0.444	127
J Invest Dermatol	0.442	87
ISIS	0.435	10
Ann Rev Biophys Bio	0.421	8
Biochim Biophys Acta	0.400	882

The effects of the immediacy index were not dissimilar (see Tables IV–V). It was observed that *Biochimica et Biophysica Acta* also received the greatest number of references in 1980 to papers published in that same year; *Advances in Immunology* was also the publication in the sample which was assigned the highest immediacy index. *Biochimica et Biophysica Acta* ranked 24th among the publications in the sample in terms of the immediacy index, although the papers which this journal published in 1980 were cited in 1980 at a rate 670 percent higher than the rate at which the source items published by *Advances in Immunology* were cited during the same interval. Even more striking was the case of *Progress in Nuclear Magnetic Resonance Spectroscopy*, which published two papers in 1980, one of which received a single citation in the same year. On the basis of these two data, this publication was awarded a ranking in terms of the immediacy index which was substantially higher than that of the *Journal of Medical Chemistry*, whose publications in 1980 were cited 127 times during the same year, the *Journal of Investigative Dermatology*, whose publications in 1980 were cited 87 times, or *Biochimica et Biophysica Acta*, whose publications for 1980 received a total of 882 citations within that same span of time.

CONCLUSIONS

The purpose of the investigation was to determine if either the impact factor or the immediacy index provides useful insight into the qualitative relationships which influence patterns of publication and citation in the primary literature of science. Although it must be admitted that the two measures are useful in that each facilitates the identification of what is most probably the relatively small number of scientific journals which receive disproportionately high number of citations, the findings of the investigation reported herein indicate that the measures are otherwise uninformative derivations, which produce an order not dissimilar to that which is produced by uncorrected rates of citation and which fail in most instances to furnish genuinely useful insight or guidance in regard to the relative quality of scientific journals.

This is not to suggest that the notion of correcting rates of citation should necessarily be abandoned, for subsequent research in this area involving the consideration of other potentially influential variables could produce results of an interesting, unob-

vious nature. However, it is also conceivable that the idea of correcting rates of citation in order to offset advantages in potential for citation is one of fundamentally distortive effect, in that the various factors which define the potential for citation and determine the rates of citations may each be integral, and none truly peripheral, aspects of such literary interaction.

In matters of advantage and disadvantage among journals, the evidence at hand suggests that correcting rates of citation in the manner of Garfield often produces a pronounced advantage for journals which publish sparingly, though the purpose of so correcting rates of citation is diminuition of advantage.

It is interesting to note that publications with higher indices of "immediacy" tend to produce higher measures of "impact". Half of the journals listed in Table V, that being the list of the publications in the sample which produced the highest immediacy indices, also appear in Table III, that being the list of journals in the sample which produced the highest impact factors. Even more telling are the relationships which may be observed upon the basis of uncorrected rates of citation. Of the journals whose papers were cited most frequently in the year of their publication, 80 percent also attained similarly high ranking in terms of citation to papers that had been published in the two preceding years, and 75 percent were among the titles that were ranked highest by citations to all years. Such facts suggest that the degree of more immediate response to the papers in a journal may exert a significant influence upon subsequent patterns of citation, and that there is underlying such patterns a "citation-breeds-citation" mechanism not unlike and quite possibly related to the so-called "Matthew effect."[8] Or, as Price noted in presenting his theory of cumulative advantage, the publication of papers "produces a first pulse of citations which in most cases probably determines all future citation history."[9] Given the distinct possibility that the more immediate response to the contents of journals in the form of citations is governed to a significant extent by the frequency of issuance, volume of publication and size of readership, it may not be unwarranted to speculate further that the rates at which journals are cited are influenced as much by the circumstances and conditions of their publication as by the intellectual reception of their contents. A careful examination of such possibilities, incorporating an array of data far broader than the perspectives of this study allowed, should be undertaken.

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