Available online at www.sciencedirect.com
ScienceDirect
Journal of Informetrics 2 (2008) 128–135
Journal of INFORMETRICS An International Journal
www.elsevier.com/locate/joi

The Reference Return Ratio

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Received 2 October 2007; received in revised form 4 December 2007; accepted 6 December 2007

Abstract

The paper introduces a new journal impact measure called *The Reference Return Ratio* (3R). Unlike the traditional Journal Impact Factor (JIF), which is based on calculations of publications and citations, the new measure is based on calculations of bibliographic investments (references) and returns (citations). A comparative study of the two measures shows a strong relationship between the 3R and the JIF. Yet, the 3R appears to correct for citation habits, citation dynamics, and composition of document types – problems that typically are raised against the JIF. In addition, contrary to traditional impact measures, the 3R cannot be manipulated ad infinitum through journal self-citations.

Keywords: Journal impact measures; Citation habits: Citation dynamics; Document types; Journal self-citations

1. Introduction

In his paper on the history of the development of the Journal Impact Factor (JIF), Cameron (2005) highlights the usage of the measure in academia. He makes clear that the measure was originally invented to assist the Institute for Scientific Information (ISI) in selecting journals for coverage in their various products. It was NOT intended to be used for other purposes. Yet, Cameron (2005, p. 113) concludes that "[w]e are left in a situation where impact factors are now routinely used to evaluate scientists, departments, entire institutions, and even nations". Over the years, a number of alternative journal impact measures have been proposed (consult e.g., Glänzel & Moed, 2002). However, none of these measures appear to have had much impact on bibliometric research including research evaluation. Moed (2005, p. 1995) notes that "the [. . .] journal impact measure is nowadays so widely dispersed and so frequently used that it seems difficult, if not impossible, to have it replaced by a single alternative measure, especially in the near future". We fully agree. Moreover, as pointed out by Rousseau (2002), the quality of a journal is a multifaceted notion necessitating a whole battery of indicators. The aim of this paper is consequently not to introduce a single measure that can fully replace the JIF, but instead to present and discuss an additional measure for the battery.

The measure introduced here is called *The Reference Return Ratio* (3R). It is based partly on an existing impact measure (the citation factor (Yanovsky, 1981)), yet developed further. It is well known that the average number and age of references per article affect the probability of being cited (see, e.g., Moed, Burger, Frankfort, & van Raan, 1983; Seglen, 1997). In the following we intend to demonstrate, that by taking the number and age of references into

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doi:10.1016/j.joi.2007.12.001

account, the 3R avoids some of the problems facing the traditional impact measures, and, consequently, that the 3R is a noteworthy supplement.

2. Related measures

Arguing that "it is better to make quantitative comparison of citations with citations and articles with articles", Yanovsky (1981, p. 229) proposed the 'citation factor'.

The citation factor is denoted as CF(Y), and defined as:

$$\mathrm{CF}(Y) = \frac{\sum_{i=0}^{Y} \mathrm{CIT}(Y, i)}{\sum_{i=0}^{Y} \mathrm{REF}(Y, i)} \tag{1}$$

CIT (Y, X) denotes the number of citations received in the year Y, by articles published in the year X. Similarly, REF(Y, Z) denotes the number of references in the articles published by the same journal in the year Z. The citation factor CF(2004) of journal J is thus calculated by dividing the number of references cited by J in 2004 with the citations received by J in 2004

It should be noted that similar measures have been suggested by others. Pinski and Narin (1976) introduced a measure similar to the citation factor of Yanovsky but excluding self-citations. This indicator measures "the influence weight of the journal, a size independent measure of the weighted number of citations a journal receives from other journals, normalized by the number of references it gives to other journals" (Pinski & Narin, 1976, p. 298). Price (1981) proposed a method for analyzing square matrices. In the worked examples "each nation or journal has an export size, an import size and some sort of self-interest (e.g., self-citation)" (Price, 1981, p. 62). The method is based on interaction and the degree of interdependence between the journals included. However, the model only considers the import and export between the included journals and does not consider the investments and returns of the single journal.

The suitability of the citation factor in journal evaluation is restricted. Although Yanovsky's measure is appealing at first sight, it suffers nonetheless from an important problem. It operates with identical time periods in both the numerator and the denominator. For instance, in one of his examples, Yanovsky (1981, p. 229) computes the citation factor of a journal by weighting the journal's 874 cited references in the year 1975 against the 256 citations received by the same journal in 1975. Today, there seem to be general agreement about the necessity for operating with longer time windows. Glänzel and Schoepflin (1995) conclude that a 3-year citation window is a good compromise between the fast obsolescence of some fields (e.g., nanotechnology) and the slow obsolescence of other fields (e.g., theoretical mathematics). Consequently, we suggest expanding the citation window to 3 years and to use the following notation:

- n_p denotes the length of the publication period;
- n_c denotes the length of the citation window;
- Y_p is the first year of the publication period;
- Y_c is the first year of the citation period.

Then the reference impact factor of an article set S is denoted as R-IF$_\mathrm{S}$ (n_p, n_c, Y_p, Y_c), and defined as:

$$\text{R-IF}_\mathrm{S}(n_\mathrm{p}, n_\mathrm{c}, Y_\mathrm{p}, Y_\mathrm{c}) = \frac{\sum_{i=0}^{n_\mathrm{p}-1} \sum_{k=0}^{n_\mathrm{c}-1} \mathrm{CIT}(Y_\mathrm{c}+k, Y_\mathrm{p}+i)}{\sum_{i=0}^{n_\mathrm{p}-1} \mathrm{REF}(Y_\mathrm{p}+i)} \tag{2}$$

Calculating an R-IF is done using the same data in the numerator, but exchanging the data on citable items in the denominator with data on references in the same or all publications. An R-IF(5,5,2000,2000) is to be understood as the number of citations received in the years 2000–2004, by articles published in the years 2000–2004 divided by the total number of references in publications published in 2000–2004. Although this measure is definitely more suitable than the first, it still gives an unfair advantage to journals in fast obsolescence fields.

3. The Reference Return Ratio

The traditional JIF and related impact measures (e.g., the aforementioned R-IF) favor journals that publish in fast obsolescence fields – i.e. fields in which ideas are turned over quickly or where knowledge is added to fre-

quently. Seglen (1997) has, for instance, pointed out that in highly dynamic research fields, such as biochemistry and molecular biology, where published reports rapidly become obsolete, a large proportion of citations are captured by the 2-year citation window traditionally used to calculate JIFs. However, fields with a more long-lasting literature, such as mathematics, have a smaller fraction of short-term citations and hence lower journal impact factors. He consequently concludes that "citation habits and citation dynamics can be so different in different research fields as to make evaluative comparisons on the basis of citation rate or journal impact difficult or impossible" (Seglen, 1997, p. 501).

Seglen (1997) raises other problems that face the JIF. Among these is the well-known problem related to the composition of document types. Review articles have been found to be heavily cited and to inflate the impact factor of other journals, and long articles have been found to collect many citations and to produce high journal impact factors.

We believe that the problems of citation habits, citation dynamics, and composition of document types may be dealt with at least to some extent by modifying the denominator of the R-IF. Instead of counting all references in the denominator, we suggest employing a reference period. This small adjustment ensures more equal evaluation conditions. Journals that publish research in fields in which ideas turn over quickly cite a high proportion of recent publications and receive a high proportion of citations soon after being published. Conversely, journals in fields characterized by long-lasting literature cite a small proportion of recent publications and receive a small proportion of citations soon after being published. Thus, by establishing the 3R on short-term bibliographic investments (references) and returns (citations) it should be possible to correct for both the problem of citation habits and the problem of citation dynamics. The problems related to composition of document types also seems to be adjusted for as the high citation rates of review articles and long articles are balanced by the extensive reference lists normally produced by these document types.

The modified notation is as follows:

- n_p denotes the length of the publication period;
- n_c denotes the length of the citation window;
- n_r denotes the length of the reference period;
- Y_p is the first year of the publication period;
- Y_c is the first year of the citation period;
- Y_r is the first year of the reference period.

The 3R of an article set is consequently denoted as 3R (n_p, n_c, n_r, Y_p, Y_c, Y_r) and defined as:

$$3R_S(n_p, n_c, n_r, Y_p, Y_c, Y_r) = \frac{\sum_{i=0}^{n_p-1}\sum_{k=0}^{n_c-1}\mathrm{CIT}(Y_c+k, Y_p+i)}{\sum_{j=0}^{n_r-1}\sum_{i=0}^{n_p-1}\mathrm{REF}(Y_r+j, Y_p+i)} \quad (3)$$

A 3R(2,2,2,2002,2004,2000) is to be understood as the number of citations received in 2004–2005, by articles published in 2002–2003 divided by the number of references in publications from 2002 to 2003 to publications published in 2000–2001.

In the following example we illustrate the calculation of the 3R using a selection of economics journals.

4. 3R contra JIF

The following comparative study investigates the characteristics of the 3R and relates it to the JIF using multiple linear regressions on a larger dataset.

4.1. Data

The comparative study is based on data from 32 economics journals. 3Rs are calculated for 1986, 1988, 1990, 1992, 1994, 1996, 1998, 2000 and 2002. A publication period of 1 year, a citation window of 3 years and a reference period of 3 years are employed. The 3R for 1990 is denoted as 3R(1,3,3,1990,1990,1988), which implies that the total number of citations received in 1990–1992, by articles published in 1990 is divided by the number of references in publications from 1990 to publications published in 1988–1990. In addition, a 3-year diachronous JIF is calculated.

The JIF calculation for 1990 is denoted as IF(1,3,1990,1990) which indicates that the number of citations received in 1990–1992 to publications published in 1990 is divided by the number of citable units published in 1990.

A number of variables have been added to test the robustness of the two measures. A short description of the variables is offered in the following (for further explanation consult Frandsen, 2007):

- The composition of document types each year. Documents are divided into seven categories (article, review, letter, note, editorial, book review, and other). The categories consist of just the document type indicated in the category label. The only exception is the 'other' category that consists of discussion, item about an individual and that sort of publications. These document types are aggregated as there are so few of them, and as the use of them varies considerably over the years.
- The total number of publications of each journal.
- The number of documents included by the ISI (article, review and note) and their share of the total number of documents.
- Geographic location of journal.
- Share of publications not in English.
- Self-citing rate.
- Self-cited rate (transformed). The variable is transformed as the relationship is non-linear. The transformation is done as follows: 1 divided by self-cited rate. Consequently a much better fit is achieved.

The three citation indexes (Arts & Humanities Citation Index (A&HCI), Science Citation Index (SCI) and Social Sciences Citation Index (SSCI)) were used in order to retrieve citations received from outside the discipline. However, it is important to keep in mind that only citations from journals covered by ISI are retrieved.

4.2. Results

Table 1 displays the journals sorted by 3R, the references and citations used in the calculation of 3R, and JIF.

Fig. 1 illustrates a strong relationship between the 3R and the JIF. The strong relationship is expected as the numerator in both expressions is identical. However, the correlation is not complete. A number of journals with very high JIFs score relatively low on 3R. Further analysis revealed that in some cases it is journals containing a considerable amount of 'not citable units' (publications not included in the calculation of JIF). In other cases it was journals publishing a very low number of relative lengthy articles each year. An example is *Brookings Papers on Economic Activity* that published 12 publications in 2000 with an average length of 58 pages.

Using a univariate regression analysis to test the correlation, we find the coefficient of the dependent variable to be 0.102 with a p-value <0.01. Other central information in the outcome is the R square of the model that summarizes the fit of the model. In this case the R square of the model is 0.452, which indicates that we are able to explain 45.2%

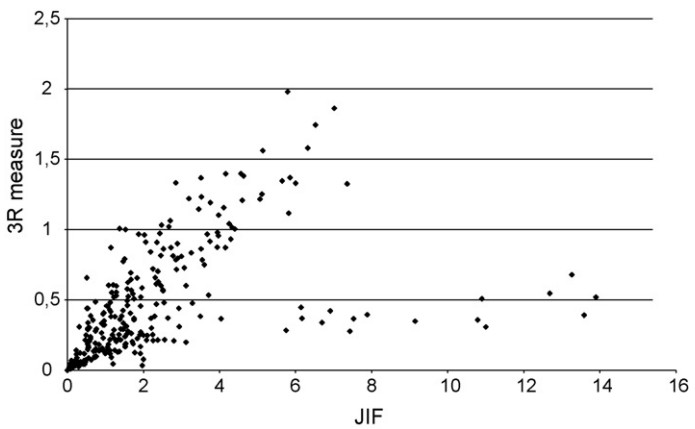

Fig. 1. 3R and JIF.

Table 1
JIFs and 3R for a selection of economics journals

Journal	2002 JIF	References[a]	Citations[b]	2002 3R
Ekonomiska Samfundets Tidskrift	0.100	83	2	0.024
Developing Economies	0.190	190	8	0.042
Desarollo Economico	0.119	237	10	0.042
Economic History Review	0.689	654	30	0.046
Jahrbücher Für Nationalökonomie und Statistik	0.174	218	13	0.060
Eastern European Economics	0.233	137	10	0.073
World Economy	0.667	522	70	0.134
Kyklos	0.590	193	26	0.135
Journal of Economic Issues	0.348	348	48	0.138
American Journal of Economics and Sociology	0.203	108	16	0.148
Explorations in Economic History	0.361	75	12	0.160
Bulletin of Indonesian Economic Studies	0.812	143	29	0.203
Brookings Papers on Economic Activity	1.500	200	42	0.210
World Development	1.227	1235	264	0.214
Cambridge Journal of Economics	0.506	109	26	0.239
Journal of Economic Literature	4.400	573	205	0.358
Scandinavian Journal of Economics	0.531	105	40	0.381
Economica	0.615	72	33	0.458
Economics Letters	0.361	335	163	0.487
Economic Journal	1.723	507	271	0.535
Oxford Economic Papers	0.642	75	45	0.600
American Economic Review	1.655	835	502	0.601
RAND Journal of Economics	1.312	151	91	0.603
European Economic Review	1.169	342	215	0.629
Journal of Econometrics	1.320	290	209	0.721
Review of Economic Studies	1.789	152	127	0.836
Journal of Economic Theory	0.816	307	299	0.974
International Economic Review	0.817	84	84	1.000
Econometrica	2.163	350	423	1.209
Review of Economics and Statistics	1.383	149	182	1.221
Journal of political Economy	2.622	205	281	1.371

[a] The number of references in publications from 2002 to publications published in 2000–2001.
[b] The number of citations received in 2002, by articles published in 2000–2002.

of the variance in the dataset. The 3R is not perfectly correlated with the JIF and thus that the two indicators are not describing identical phenomena.

As described earlier, one of the characteristics of the 3R is that it does not directly distinguish between different document types in the denominator as done in the ISI JIF. Indirectly it does, however, since different document types tend to contain more or less references. It is well known that document types that typically cite a low number of references also typically are less cited (e.g., book reviews (Diodato, 1984; Nicolaisen, 2002)), while document types that typically cite a high number of references typically are also more cited (e.g., review articles (Garfield, 1972; Moed, Van Leeuwen, & Reedijk, 1996.). We would thus expect the composition of document types to be less influential. Fig. 1 lends some credence to the hypothesis. The two indicators seem to treat journals with certain compositions of document types differently. Tables 2 and 3 present the results of univariate and multivariate linear regression analyses investigating the influence of 3R and JIF by composition of document types.

First of all, the substantial differences in R squares are noticeable. In the case of JIF we are able to explain 50% of the variation in the dataset by composition of document types as many of the variables proved to be significantly influential on JIF. However, in the case of the 3R we are only able to explain 13% of the variation in the dataset because none of the document types nor the total proved to be significantly influential on the 3R. As expected the 3R is not under influence of the composition of document types and this leads us to suggest that the 3R do correct for composition of document types. The various document types are characterized by different patterns in the number of references and this is why JIF and the 3R are so closely related. Although highly related, they describe different aspects of journals as illustrated by the fact that JIF is influenced by composition of document types whereas the 3R is not.

Table 2
Multivariate linear regression analysis

Variable	JIF		3R	
	Coefficients	*p*-Value	Coefficients	*p*-Value
Intercept	1.620	0.000	0.000	<0.01
Article	0.110	<0.1	–	–
Review	0.587	<0.01	–	–
Letter	0.313	<0.05	–	–
Note	0.130	<0.05	–	–
Editorial	–	–	–	–
Book review	0.120	<0.05	–	–
Total	−0.110	<0.1	–	–
R squared	0.507		0.130	
Observations	288		288	

Dependent variable is JIF and 3R.

Before introducing the outputs of the two final models we have to make a note concerning the document types. We tried running the models including all the document types but the high number of variables weakened the model considerably and very few turned out to contribute to the understanding of JIF and the 3R. Therefore we only include the document types in aggregated forms. We investigate the influence of the total number of publications, the number of publications with the most scientific content (citable units and the share of these publications). The data and the results of the analysis of JIF presented in Table 3 are only described and analyzed in relations to the output of the similar regression of the 3R as the analysis of JIF is done with very similar results in Frandsen (2007).

Both models have relatively high *R* squares which indicate that the model is a good fit. We are able to explain 60 and 70% of the variations in the datasets.

Both the JIF and the 3R are positively correlated with the total number of publications. The coefficient of 0.001 of the 3R is to be understood like this: If a journal editor increases the total number of documents published in the journal each year by 10 we will expect to see an increase in the 3R by 0.01. The variables describing the self-citing rate and self-cited rate are affecting the distribution of the two measures across journals similarly for both indicators. Consequently, a journal may boost its JIF and 3R by journal self-citations. However, contrary to other impact measures, the 3R cannot be manipulated ad infinitum. The self-citation manipulation maximum is 1.0 as all self-citations are also 'self references' and thus counted in both the numerator and denominator of the 3R.

The variable describing geographic location is negatively correlated with JIF but no correlation is found with the 3R. This is also the case with the variable describing the share of publications not written in English. As the multiple linear regression only presents statistical tendencies in the dataset further research is needed if we are to understand why the 3R is not negatively correlated with these variables as the JIF is.

Table 3
Multivariate linear regression analysis of 3-year diachronous JIF and 3R

Variable	JIF		3R	
	Coefficients	*p*-Value	Coefficients	*p*-Value
Intercept	2.179	<0.01	−0.0438	<0.01
Geographic location of journal	−1.323	<0.01	–	–
Share of publications not in English	−1.041	<0.01	–	–
Self-citing rate	16.025	<0.01	10.380	<0.01
Self-cited rate (transformed)	0.200	<0.01	0.26	<0.01
Document types included in ISI-JIF	−0.008	<0.01	–	–
Share of ISI-included documents of total	−2.069	<0.01	0.393	<0.01
Total number of documents	0.004	<0.05	0.001	<0.05
R squared	0.609		0.701	
Observations	288		288	

Furthermore, JIF is negatively correlated with the number of documents included in the calculation of the ISI JIF. The coefficient of −0.008 implies that an increase in the number of documents included in the ISI calculation of JIF by 100 the JIF leads to a decrease in JIF by 0.8. This aspect is further described by the variable of the share of document types included in the ISI calculation of JIF as it is also significant at the 0.01 level and the coefficient is negative. We interpret the correlation of these two variables combined with the coefficient of the variable describing the total number of documents as: An increase in the total number of documents (excluding the publications included in the ISI calculation of JIF) will lead to an increase in JIF all other things being equal. The 3R is not correlated with the number of documents included in the calculation of the ISI JIF. Opposite to the JIF, the variable of the share of document types included in the ISI calculation of JIF is positively correlated with the 3R. We interpret this as: An increase in the total number of documents (regardless of being included in the ISI calculation of JIF) will lead to an increase in the 3R.

In the results we can see that some of the characteristics of JIF are the same when we analyze the 3R. The variables describing the number of publications, the self-citing rate and the self-cited rate are affecting the distribution of the two measures across journals similarly. Furthermore the results clearly support our initial hypothesis that the 3R is not influenced by the composition of document types. Finally, the variables describing geographic location of the journal and the share of publications not written in English do not affect the distribution of the two measures across journals similarly.

5. Discussion and conclusion

Traditionally, impact has been measured in the currency of received citations. Authors, journals, institutions, and countries are frequently evaluated and compared using this yardstick. The success of the individual is relative to the success of 'the others' – just like personal success in all markets is relative to the success of the other players.

The market analogy is not a new construct in bibliometrics. It has, for instance, been used before as a starting point for explaining citation behavior. In fact, both supporters and skeptics of citation analysis have used the analogy to argue their cases. Merton (1979, p. viii) argued, for instance, that "[c]itations and references operate within a jointly cognitive and moral framework. In their cognitive aspect, they are designed to provide the historical lineage of knowledge and to guide readers of new work to sources they may want to check or draw upon for themselves. In their moral aspect, they are designed to repay intellectual debts in the only form in which this can be done: through open acknowledgment of them". Merton's view on citations and references was consequently based on the idea that science resembles a market where scientists are supposed to exchange information in the form of publications for recognition in the form of citations. It echoes Hagstrom's (1965) idea that the process is a form of barter.

Among the skeptics, Law and Williams (1982, p. 543) have equated scientists' choice of references to that of "packaging a product for market", and MacRoberts and MacRoberts (1996, pp. 440–441) have stated that "papers are meant to sell a product" and, consequently, that "[a]n author's main objective is not to cite their influences but to present as authoritative an argument as possible". These claims are in line with the so-called 'persuasion hypothesis' (Gilbert, 1977) – the idea that persuasion in science and scholarship relies on misleading manipulation indistinguishable from commercial advertising.

Although supporters and skeptics of citation analysis clearly disagree over how the market mechanisms work, they seem to agree that references and citations at least possess some value or worth. This belief is shared by a number of economists. Diamond (1986) has actually tried to establish the worth of a citation by studying the relationship between salaries and number of citations among scientists, and Toutkoushian (1994) has used citation counts to measure sex discrimination in faculty salaries.

Intuitively, the market analogy also makes sense as a theoretical framework for the 3R. There is a clear association between bibliographic investment (references) and return (citations). Yet, the fact that the ISI citation indexes are not representing a closed market may limit the practical potentials of the market analogy.

Our results show that there is a strong relationship between the 3R and the JIF. Yet, the 3R appears to correct for citation habits, citation dynamics, and composition of document types – problems that typically are raised against the JIF. In addition, contrary to traditional impact measures, the 3R cannot be manipulated ad infinitum through journal self-citations.

Although the 3R avoids some of the problems facing the traditional JIF and related impact measures, it also faces some of the same problems and challenges. As pointed out by Case and Higgins (2000, p. 636), "citing a seminal discovery or a methodological breakthrough certainly is more important than citing other investigators who have

pursued the same topic". Yet, as most other citation measures, the 3R does not take the varied purposes of references and citations into account. Instead, all references and citations are treated as functionally equivalent. However, there is nothing to prevent the 3R from being applied to the measuring of weighted references and citations as well. One would only have to obtain the relevant data.[1]

A potentially more important problem concerns the possible biases of editorial practices. The citation counts of the 3R are influenced by the editorial practices of many journals whereas the reference counts are affected by the editorial practices of just a single journal. Consequently, special editorial practices could potentially affect the referencing practices of the authors writing for a particular journal, and thus the results of its 3R. However, an extensive search for literature that could facilitate an estimation of the magnitude of this potential problem retrieved no results of relevance.

Acknowledgement

The authors would like to thank Ronald Rousseau and two anonymous referees for their valuable comments.

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[1] Consult Smith (1981, pp. 89–91) for a discussion of different weighting methods.