

How are New Citation-Based Journal Indicators Adding to the Bibliometric Toolbox? *

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Abstract

The launching of Scopus and Google Scholar, and methodological developments in Social Network Analysis have made many more indicators for evaluating journals available than the traditional Impact Factor, Cited Half-life, and Immediacy Index of the ISI. In this study, these new indicators are compared with one another and with the older ones. Do the various indicators measure new dimensions of the citation networks, or are they highly correlated among them? Are they robust and relatively stable over time? Two main dimensions are distinguished—size and impact—which together shape influence. The H-index combines the two dimensions and can also be considered as an indicator of reach (like Indegree). PageRank is mainly an indicator of size, but has important interactions with centrality measures. The Scimago Journal Ranking (SJR) indicator provides an alternative to the Journal Impact Factor, but the computation is less easy.

Introduction

In a seminal article about citation analysis as a tool in journal evaluation, Garfield (1972: 476) advocated the Journal Impact Factor in order to normalize for the expected relation between size and citation frequency. On the basis of a sample of the *Science Citation Index* 1969, he concluded that from 21 to 25 percent of all references cite articles that are less than three old (Martyn & Gilchrist, 1968), and therefore one might define the Journal Impact Factor as the average number of citations in a given year to citable items in the two preceding years. As is well known, this has become the Journal Impact Factor in use by the ISI (Thomson Reuters) and in a large number of evaluation studies.

In later studies, the ISI (Garfield, 1990, 1998) experimented with time windows of five and even fifteen years. The Impact Factor was further formalized and generalized by Frandsen & Rousseau (2005) and by Nicolaisen & Frandsen (2008). However, in a Letter to the Editor of *Information Processing and Management*, Garfield (1986) argued on substantive grounds against the use of five-year Impact Factors: one should not confuse impact with influence. The Impact Factor does not measure the impact or influence of a journal, but of an average item published in that journal. In other words, it could imply an “ecological fallacy” to infer from the average quality of trees to the quality of the woods as a whole (Robinson, 1950). In the case of journals, the size of the journal also plays a role, or as Garfield adds: “Surely it should be obvious that influence is a combination of impact and productivity.” (*Ibid.*, p. 445). Unlike the impact of the average, productivity can be indicated by the total number of documents and/or the total number of citations, publications, etc.

In addition to a breakdown of the citations by year (for the last ten years), the *Journal Citations Reports* of the Institute of Scientific Information (Thomson-Reuters ISI) provide a number of other indices. Most relevant in this context—since citation-based—are the Immediacy Index and the journal’s Cited Half-life. The Immediacy Index provides the

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number of citations an item obtains in the year of publication itself. The cited half-life of a journal is the median age of its articles cited in the current *JCR* year. In other words, half of the citations to the journal are to articles published within the cited half-life. Yue *et al.* (2004) found a high correlation between the Impact Factor and the Immediacy Index.

More recently, new indicators have been proposed, such as the H-index (Hirsch, 2005) and the so-called Scimago Journal Rank (SJR) using data from Scopus. The H-index is most popular and has been included in the online version of the *Science Citation Index-Expanded* of the ISI for any set of documents. The H-index was originally defined at the author level: a scholar with an index of h has published h papers each of which has been cited by others at least h times. However, like the other measures it can be applied to any document set (Braun *et al.*, 2006; Van Raan, 2006). Unlike the other measures, the H-index is time-dependent, or one might say dynamic. Given the advent of Internet-based databases such as Google Scholar, this continuous update could also be considered as an advantage. Its proponents claim that the H-index reflects both the number of publications (“productivity”) and the number of citations per publication (“impact”). Ever since its introduction a number of derived indicators have been proposed, like the G-index, the AR-index, etc., which improve on some of the shortcomings of the H-index (e.g., Egghe & Rao, 2008; Rousseau, 2008).

In 2004, Elsevier launched the Scopus database as an alternative to the ISI databases. Scopus covers more journals than the *Science Citation Index*, the *Social Science Citation Index*, and the *Arts & Humanities Citation Index* of the ISI combined. In both databases, however, the inclusion of journals is based on both quantitative information about journals and qualitative expert judgements (Testa, 1997). Criteria are not externally transparent, but this seems legitimate because of the commercial interests at stake for journal publishing houses. Scopus includes many more Chinese journals than the ISI database, but more recently there seems to be an agreement to include more regional (including Chinese) journals in the ISI domain (e.g., <http://globalhighered.wordpress.com/2008/05/29/thomson-scientific-china/>).

The two databases (*Scopus* and the *Science Citation Indices*) are both overlapping and complementary (Meho & Yang, 2006; Visser & Moed, 2008). The third database, of course, is Google Scholar, which was also launched in 2004. Google Scholar is based on crawling the Internet for scientific literature, and inclusion criteria are relaxed (albeit also not transparent): authors and publishers of scientific articles are encouraged to submit their materials. Given the design of this database which returns hits along a decreasing order of citations, the results almost invite the user to consider the H-index for a set by paging down the list till one reaches the point where the number of citations breaks even with the sequence number.

The search engine Google itself uses PageRank as an algorithm for sorting pages when displaying the search results (Page *et al.*, 1998; Brin & Page, 1998). PageRank is derived from the Influence Weights that Pinski & Narin (1976) originally proposed as an indicator of journal status (Garfield, 1979). PageRank is included in the Korean software package NetMiner; the original program of Brin & Page is freely available in the Network Workbench Tool at <http://nwb.slis.indiana.edu/> (NWB Team, 2006). I shall include PageRank in the comparison among journal indicators below.

Based on the Scopus database, the Scimago research group of the Universities of Granada, Extremadura and Carlos III in Madrid (<http://www.atlasofscience.net>) has developed the so-called Scimago Journal and Country Rank system at <http://www.scimagojr.com/index.php>. Particularly relevant for my research question is the set of journal indicators made available at <http://www.scimagojr.com/journalrank.php> . All data is brought online and available for

further research. The Scimago Journal Rank (SJR) can be considered as an equivalent in the Scopus domain to the Journal Impact Factor in the ISI domain (Falagas *et al.*, 2008).

My first research question is: do these indicators measure a common dimension in the data? Are the various indicators complementary or essentially measuring the same underlying dimension? Secondly, how do they relate to other measures of journal impact, influence, size, etc.? Thirdly, how stable are these measures over time? If considerable error were introduced by an algorithm, one would expect the resulting measures to be less stable than the raw data, e.g., Total Cites. For this reason, I also compare the data for 2007 with similar data for 2006 and provide the auto-correlations between data for these two years. In addition to comparing the journal indicators among them, I extend the analysis with some network indicators from social network analysis such as centrality measures using the same datasets.

Methods and materials

The data of the *Journal Citations Reports* of the *Science Citation Index* and the *Social Science Citation Index* are available online at the ISI Web of Knowledge (<http://www.isiknowledge.com>). In this project the data was harvested from the CD-Rom version of the databases, which are otherwise similar to the electronic versions but easier to manipulate using relational database management. The two datasets (for the *Science Citation Index* and the *Social Science Citation Index*, respectively) are combined so that one can correct for the overlap between them (342 journals in 2007 and 321 in 2006, respectively). The datasets contain 7,940 journals in 2007 and 7,611 in 2006.

The indicators based on data from the Scopus database have been made conveniently available by the Scimago team at the websites for the respective years as MS-Excel files. The data contains the total numbers of documents, references, and citations (with a breakdown for the last three years), the SJR value, and the H-index for all journals in the set. However, Total Cites are provided only for the last three years. The help-file formulates: “**Total Cites (3years)/Total Cites**: Total of document citations received by a journal in a 3 year period. This indicator is estimated taking into account of all types of documents contained in a journal in the selected year and the bibliographical references they include to any document published in the three previous years.” In another context, this indicator is compared with the Impact Factor Numerator based on using a two-year citation window retrospectively (Bensman & Leydesdorff, in print). I use this indicator as the best proxy for “Total Cites” available in the Scopus database.

Another problem with the Scimago/Scopus database is the H-index provided for each of the years. Using different dates for the download, I noted that these H-indices are updated, presumably quarterly, and then retrospectively also in the previous years. At least, we found the same values for every year at one moment in time (October 1, 2008), and different values between searches in April 2008 (when downloading the data for 2006) and June 2008 (data for 2007). However, the distribution of H-indices should vary between the years, for example, because of variations in the database coverage. In 2007, the Scopus database covered 13,686 journals as against 13,210 in 2006.

More worrisome than this understandable updating of the H-values from the perspective of hindsight—because this dynamic increase is a well-known problem of the H-index (Jin *et al.*, 2007)—is the apparent, but unexplained updating of the SJR values over time. The *Annual Review of Immunology*, for example, which ranks highest on this indicator in both 2006 and 2007, had an SJR 2006 of 23.740 on October 1, 2008, but only 22.439 in April 2008. Similarly, the second journal listed on this ranking, the *Annual Review of Biochemistry*, had

an SJR 2006 of 16.796 in September but 16.100 in April. The SJR values in 2007 are lower for both these journals, namely 20.893 and 15.691, respectively. Might these values also increase with time? The formula for calculating the SJR-values is provided at <http://www.scimagojr.com/SCImagoJournalRank.pdf> (accessed on October 4, 2008), but it does not suggest a dynamic perspective.

In this study, I used the values for 2006 as they were downloaded on April 23, 2008, and the values for 2007 as downloaded on June 24, 2008, since I assumed that the databases are reloaded on the occasion of the yearly update (early June). (The help-file mentions updating periodically.) Anyhow, for the statistics—which are the subject of this study—these relatively small differences are probably not so important.

In the second part of the study, I also use network centrality measures (Freeman, 1978/1979; Hanneman & Riddle, 2005; Leydesdorff, 2007). Six possible centrality measures (degree, betweenness, closeness, in both the “cited” and “citing” dimensions) can be calculated using Pajek. PageRank is not included in Pajek, but it is in several other programs. Both NetMiner and the original program of Brin & Page (as included in the Network Workbench at <http://nwb.slis.indiana.edu>) were used to calculate PageRanks for the journals in 2006 and 2007. The results were identical for the (default) damping factor $d = 0.15$ and ten bins. I also used other parameters; this will be discussed in the results section.

Let me first focus on the static analysis for 2007. After a factor analysis and correlation analysis of the various journal indicators for 2007, I shall add the centrality measures to the domain in order to see whether and how they contribute to understanding the matrix and the indicators. The same analysis was also done for 2006. The results are virtually similar which suggests a high degree of stability in the structure of this set of indicators. Thereafter, the various indicators are auto-correlated between the corresponding values for 2006 and 2007.

Because significance testing is dependent on the number of cases, and the number of cases in the Scopus database is much larger than in the combined ISI-databases (the *Science Citation Index* and the *Social Science Citation Index*), I used the overlap between the two databases (Table 1). The databases were matched using their full titles.

Table 1. Number of journals in the ISI-databases combined, Scopus, and the overlap.

Number of journals	ISI databases	Scopus	Overlap
2006	7,611	13,210	6,045
2007	7,940	13,686	6,210

The dynamic analysis (in terms of auto-correlations for different years) is based on the 5,861 journals included in both databases in both 2006 and 2007.

Results

Journal indicators

Let us first limit the analysis to the typical journal indicators. These are the size indicators such as total numbers of citable documents, total numbers of references and citations, the Impact Factor, Immediacy Index, Cited Half-life, the SJR, and the H-index. I also added PageRank to this set since this indicator is commonly known because of its use in the Google database. Furthermore, PageRank can be considered as an inherited revival of the so-called Influence Weights proposed in the 1970s by Pinsky and Narin (1976). However, PageRank is dependent on parameter choices like the damping factor d . While $d = 0.15$ is the default value,

some authors recommend $d = 0.85$. I found strong correlations (Pearson's $r = 0.942$, and Spearman's $\rho = 0.934$) when comparing the two extremes of $d = 0.15$ and $d = 0.85$ ($p < 0.01$; $N = 6,160$). In the factor analysis, it made *no* difference which damping factor was used for the PageRank analysis. Although PageRank is a network indicator, I decided to include it as a journal indicator in the first round of the analysis because of its origins in the journal domain (Pinski & Narin, 1976).¹

A three-factor solution explains 82.8% of the common variance. (These three components explain 55.1, 19.5, and 8.2%, respectively.) Table 2 provides the factor solution based on Varimax rotation and Kaiser normalization. Figure 1 shows the scatterplot using the two main components. Obviously, "Cited Half-life" provides the third (latent) dimension in this data-structure. This variable does load (slightly) negatively on the first two dimensions.

Table 2. Results of the factor analysis for journal indicators.

	1	2	3
Total Citing (ISI)	.951	.147	
Total Docs. (ISI)	.944		
Total Citing (Scopus)	.942	.152	
Total Docs. (Scopus)	.932	.125	
Self-Citations (ISI)	.831		
Total Cited (Scopus)	.773	.456	.139
Total Cited (ISI)	.763	.407	.213
PageRank ($d = 0.85$)	.729		-.112
Impact Factor	.135	.951	
Immediacy Index		.895	
SJR		.878	
H-index	.577	.671	.222
Cited Half-life			.963

Extraction: Principal Component Analysis. Rotation: Varimax with Kaiser Normalization.

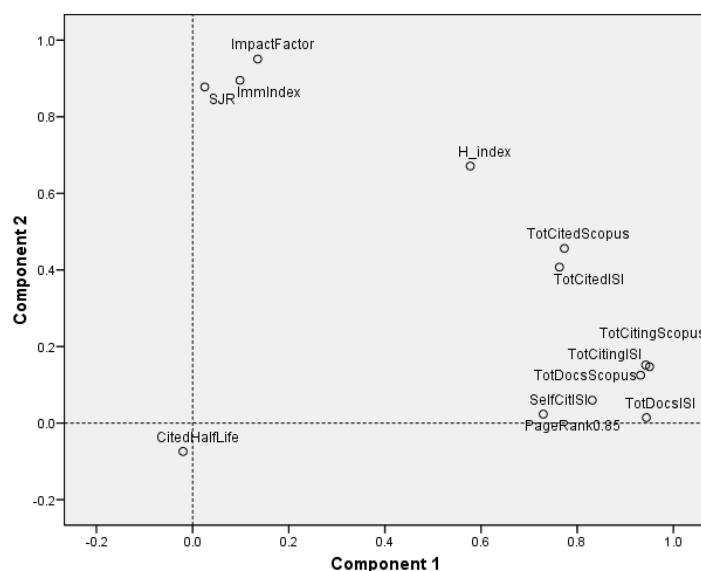


Figure 1. Scatterplot of the journal indicators on the two main components; $N = 6,210$.

¹ Bollen & Van de Sompel (2006) used a weighted PageRank on the aggregated journal-journal citation matrix of the ISI; Bergstrom (2007) used the eigenfactor-value as a proxy for PageRank and posted the results online at <http://www.eigenfactor.com>.

Component One represents the size factor, Component Two the impact. We can follow Garfield (1986) by concluding that influence is indeed a combination of productivity (size) and impact. Among this set of indicators, PageRank Centrality is obviously a size indicator. The H-index, however, combines the two dimensions more than any of the other indicators. This characteristic may explain its almost instant popularity among research evaluators.²

Table 2 further informs us that the numbers of references and the numbers of documents are highly correlated, and these values in either database can be used as indicators of the size dimension. Self-citations also follow on this size dimension. The numbers of citations (“Total Cited”) in the Scopus and the ISI-database are correlated with $r = 0.94$ ($p < 0.01$; $N = 6,160$) despite the different definition of Total Cites in the Scopus database. By limiting the citation window to the last three years, Total Cites in the Scopus database loads a bit higher on the impact dimension because of the increase in focus on the research front.

Another way of designating the two factors would be to consider the first size-related factor as indicating the archival function, and the second one as indicating the research front (Price, 1965). As mentioned, the Impact Factor and the Immediacy Index correlate closely, but the new ranking indicator SJR also correlates in this dimension. The Impact Factor correlates less with the SJR measure ($r = .796$) than with the Immediacy Index ($r = .877$); as Figure 1 shows, SJR is slightly more orthogonal to the size dimension than the Impact Factor. This means that it normalizes for size a bit more strongly than the Impact Factor already does.

Recently, Zitt & Small (2008) proposed the Audience Factor (AF) as an alternative to the Impact Factor (IF). These authors used 5,284 journals from the *Journal Citations Reports* 2006 of the *Science Citation Index*, of which 4,277 belong to the sets studied in this research. Furthermore, they used five-year citation windows (AF5 and IF5, respectively). Using these 4,277 journals and including these two variables, I generated Figure 2, which is based on adding these two indicators (AF5 and IF5) to the set.

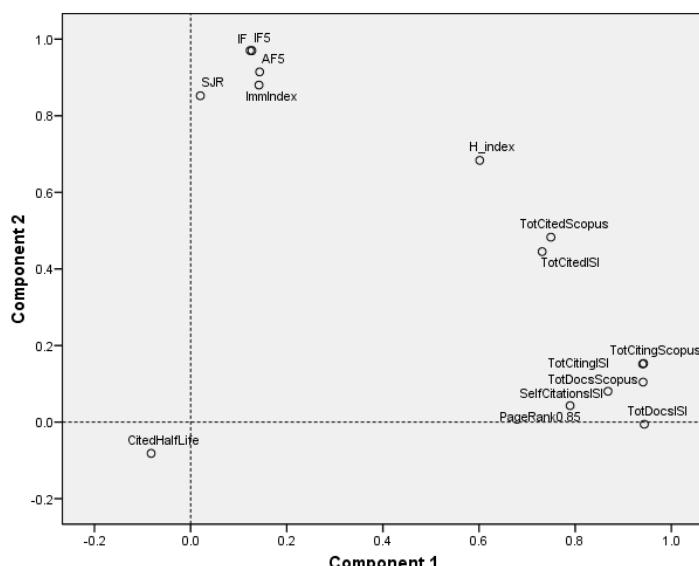


Figure 2. Scatterplot of the journal indicators 2006 on the two main components; audience factor added; $N = 4,277$.

² A four-factor solution—the fourth factor explains an additional 5.3% of the common variance—further differentiates between the Total Cited, on the one hand, and the Total Citing and the PageRank, on the other.

Table 3. Pearson correlation coefficients for the Audience Factor (AF5) with the other impact indicators

		IF5	IF	Immediacy Index	SJR
AF5	Pearson Correlation	.956(**)	.921(**)	.790(**)	.685(**)
	Sig. (2-tailed)	.000	.000	.000	.000
	N	4277	4277	4191	4277

** Correlation is significant at the 0.01 level (2-tailed).

Table 3 provides the correlations of the AF5 with the other impact indicators. A comparison of Figure 2 with Figure 1 shows (1) how robust the two factor solutions are when comparing 2006 and 2007, and (2) that the Audience Factor does not add structurally to the set of indicators already available.

Network indicators

Let me now add the six centrality indicators that were derived from social network analysis to this system of journal indicators. A three-factor solution in this case explains 74.5% of the common variance, but the screeplot indicates that a five-factor solution should be considered (85.7%; eigenvalues > 1.0). If we choose this five-factor solution, the network indicators add a third and a fourth dimension to the three-factor solution of the journal indicators discussed above. The “Cited Half-life” remains a final (fifth) factor (to be discussed below).

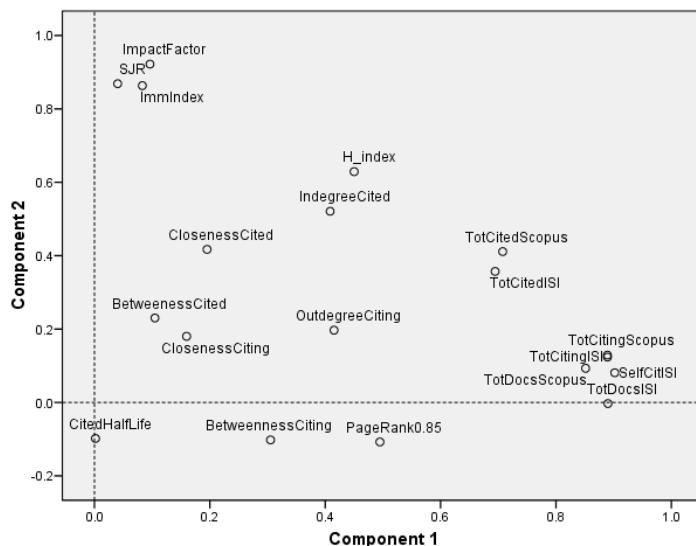


Figure 3. Scatterplot of the two main components of a five-factor solution including the network indicators ($N = 6,210$).

Figure 3 illustrates how the network indicators can be projected using the two axes spanned by the journal indicators as the first two components. The only journal indicator that is sensitive to the addition of the network indicators is PageRank, because this is an indicator based on graph theory. Because of the formula of the SJR—provided at <http://www.scimagojr.com/SCImagoJournalRank.pdf> (accessed on October 4, 2008)—one would expect this indicator also to be sensitive to the addition of network indicators, but this is hardly the case. In other words, the SJR is indeed a journal impact indicator.

Table 4. Five-factor solution for the set of journal and network indicators ($N = 6,210$).

	1	2	3	4	5
Self-Citations (ISI)	.902				
Total Docs. (ISI)	.890		.323		
Total Citing (ISI)	.889	.124	.366		
Total Citing (Scopus)	.889	.129	.338		
Total Docs. (Scopus)	.851		.324	.194	
Total Cited (Scopus)	.708	.411	.128	.459	
Total Cited (ISI)	.695	.357		.540	.128
Impact Factor		.922	.185	.102	
SJR		.869			
Immediacy Index		.863		.130	
H-index	.450	.629	.375	.300	.246
Indegree Cited	.408	.521	.520	.344	.220
Closeness Citing	.160	.180	.840		
Outdegree Citing	.415	.197	.800	.123	
Closeness Cited	.195	.417	.762		.182
PageRank ($d = 0.85$)	.495	-.108	.636	.294	-.112
Betweenness Citing	.305	-.102	.554	.550	-.119
Betweenness Cited	.105	.230		.905	
Cited Half-life					.947

Extraction Method: Principal Component Analysis; Rotation: Varimax with Kaiser Normalization.

The patterns among the network indicators are complex (Table 4). First, it is to be noticed that Indegree (that is, the number of links in the cited dimension) correlates highly with the H-index ($r = 0.89$). The Indegree can also be considered as a measure of reach, that is, the number of citation relations but without weighting for the number of citations on these relations. As could be expected, betweenness centrality is different from closeness and degree centrality (Freeman, 1977; Leydesdorff, 2007b). PageRank shares interfactorial complexity with the H-index and Indegree, but unlike the latter two PageRank correlates negatively with the indicators on the impact dimension (Factor 2).

Table 5. Pearson correlations among the network and journal indicators.
(All correlations are significant at the level of $p < 0.01$.)

Pearson correlations	Indegree Cited	Outdegree Citing	Betweenness Cited	Betweenness Citing	Closeness Cited	Closeness Citing
Impact Indicators						
Impact Factor	.602	.399	.289	.194	.448	.289
Immediacy Index	.507	.298	.282	.162	.347	.219
<i>Cited Half-life</i>	.093	-.130	.048	-.005	.012	-.167
New Indicators						
SJR	.464	.253	.186	.077	.295	.176
H-index	.890	.635	.460	.403	.632	.414
PageRank ($d = 0.85$)	.547	.744	.224	.772	.357	.430
Size indicators						
Total Docs. (ISI)	.549	.629	.182	.498	.375	.396
Total Docs. (Scopus)	.626	.647	.297	.516	.409	.381
Total Cited (ISI)	.726	.491	.643	.437	.359	.244
Total Cited (Scopus)	.736	.545	.553	.428	.379	.275
Total Citing (ISI)	.645	.724	.206	.534	.433	.405
Total Citing (Scopus)	.623	.689	.204	.517	.419	.384
Self-Citations (ISI)	.409	.385	.160	.338	.253	.212

Table 5 provides an overview of the correlations between the two types of indicators, namely the network indicators based on graph theory, and the traditional and new journal indicators. More than the other journal indicators, “Citation Half-life” does *not* correlate (positively or negatively) with the network indicators because of its focus on the time dimension. Citations are conceptually related to time, and journal indicators take this into account by using for example a two-year citation window (as in the case of the Impact Factor). Network indicators, however, do not take time into account, but are momentary. The historical dimension can be programmed into the network approach, but this has to be done explicitly (Pudovkin & Garfield, 2002; Lucio-Arias & Leydesdorff, 2008; Leydesdorff & Schank, 2008).

Stability and change

Table 6 provides the auto-correlations for the various indicators for the years 2006 and 2007, using the 5,861 journals included in both databases in both years.

Table 6. Auto-correlations between the corresponding indicator values in 2006 and 2007.

	<i>Pearson's r</i>	<i>Spearman's ρ</i>
<i>ISI-Journal Indicators</i>		
Impact Factor	0.976	0.942
Immediacy Index	0.890	0.792
Cited Half-life	0.900	0.929
<i>New Indicators</i>		
H-index (Scopus)	0.995	0.984
SJR	0.990	0.947
PageRank ($d = 0.85$)	0.828	0.841
PageRank ($d = 0.15$)	0.886	0.870
<i>Size Indicators</i>		
Total Cited ISI	0.999	0.989
Total Cited Scopus	0.989	0.969
Total Citing ISI	0.824	0.914
Total Citing Scopus	0.970	0.903
Self-citations ISI	0.989	0.926
Total Docs. ISI	0.967	0.937
Total Docs. Scopus	0.964	0.922
<i>Network indicators</i>		
Indegree (cited)	0.998	0.988
Outdegree (citing)	0.963	0.941
Betweenness (cited)	0.999	0.960
Betweenness (citing)	0.905	0.830
Closeness (cited)	0.794	0.941
Closeness (citing)	0.611	0.866

All correlations are significant at the 0.01 level; $N = 5,861$ except in the case of Cited Half-life (because of the many missing values in this case: $N = 4,701$). The main observation is that the new journal indicators (SJR and H-index) are more stable ($r > 0.99$) than the traditional ISI-indicators. As expected, all indicators in the citing dimension are less stable than in the cited one because citing as action introduces change into the database (Leydesdorff, 1993). Closeness centrality is less stable than the other network indicators ($0.61 < r < 0.79$).

Conclusions

Unlike the Impact Factor, the SJR indicator and the H-index are non-parametric, that is, they are not based on normalization to the arithmetic mean of the values in the document sets. In the case of citation data this is a clear advantage, because the data is heavily skewed (Leydesdorff, 2008). However, the H-index has the well known problem that it leads to counter-intuitive results because of the attempt to bring the size component and the impact component under a single denominator. For example, an author who has published three articles with 100 citations each and otherwise a number of articles cited fewer than three times is equally ranked at $h = 3$ with an author who has only marginally more than three citations for each of the top three articles and otherwise the same distribution. The advantage of the H-index is that it provides a single number which is easy to retrieve and remember.

The data contains two dimensions, size and impact, which—quoting Garfield—together shape influence. Any inference which jumps too easily from one dimension to another may lead to misunderstandings. As Garfield emphasized, one should not consider the Impact Factor as an indicator of the quality of a journal, but as an indicator of the average quality of articles in that journal. A comparison with the size dimension makes this point clear: the average size of an article does not inform us about the size of the journal. However, this warning against an “ecological fallacy”—that is failing to note the difference between making inferences about the aggregate of trees or of the woods—has hitherto been little heeded in studies using the Impact Factor for research evaluation (Robinson, 1950; Moed, 2005). Journals, however, are *not* homogenous entities (Bradford, 1934; Garfield, 1971).

I was surprised to find that PageRank was to such an extent *not* an impact indicator because it was developed after Pinski & Narin’s (1976) “Influence Weights,” which were designed as an alternative to Impact Factors. In another context, Hindman *et al.* (2003) found supporting evidence for these size-effects in the results of Google’s algorithm. However, the SJR, albeit derived conceptually from the PageRank concept, seems to offer a good alternative to the Impact Factor.

Indicators along the impact axis, including the newly introduced Audience Factor (Zitt & Small, 2008), are highly correlated. In an ideal world, one might perhaps like to see the SJR applied to the JCR data (Bergstrom, 2007). One advantage of the SJR is that this indicator is available as open access—although the Impact Factor values are so much circulated in practice (e.g., at <http://abhayjere.com/impactfactor.aspx>) that one can hardly consider this a serious drawback in using them. An advantage of the Impact Factor and the H-index, on the other hand, is the ease with which they can be understood. As I have shown, however, the H-index may oversimplify the complexities involved because it tries to capture both orthogonal dimensions (size and impact) in a single indicator.

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