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REVIEW ARTICLE

Diversity, value and limitations of the journal impact factor and alternative metrics

Lutz Bornmann · Werner Marx · Armen Yuri Gasparyan · George D. Kitas

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Abstract The highly popular journal impact factor (JIF) is an average measure of citations within 1 year after the publication of a journal as a whole within the two preceding years. It is widely used as a proxy of a journal's quality and scientific prestige. This article discusses misuses of JIF to assess impact of separate journal articles and the effect of several manuscript versions on JIF. It also presents some newer alternative journal metrics such as SCImago Journal Rank and the *h*-index and analyses examples of their application in several subject categories.

Keywords Bibliometrics · Periodicals as topic · Impact factor · *h*-Index · Biomedical journals · Rheumatology

Introduction

The journal impact factor (JIF) is calculated by the scientific division of Thomson Reuters (Philadelphia, PA, USA) and published annually in the Journal Citation Reports® (JCR). Initially, JCR was proposed as a guide for US University and College librarians for the evaluation of prestige and the selection of scholarly journals with the highest impact for their libraries [1]. Currently, about 11,000 high-quality journals selected by the Web of Science (WoS) are listed in JCR. These are publications with substantial citation record and high scientific prestige in certain subject categories. Due to the popularity of JIF among science editors and research evaluators worldwide, JCR has actually become a legitimate authority for ranking scholarly journals [2–5]. Moreover, JIF has been increasingly used as a parameter influencing the decision-making process for research grant allocation, hiring and promotion of academic staff [6].

The 2-year JIF is calculated based on the number of citations at all Web of Science (WoS)-indexed journals in a certain year to all the journal's items published in the two preceding years. The number of citations is then divided by the number of substantive or citable articles (i.e. original papers, reviews, short communications, medical case reports) [4]. Editorials and letters are not counted as substantive items. For example, JIF 2010 for *Arthritis Care and Research*, one of the leading rheumatological journals containing a variety of scientific articles, is calculated by dividing citations in 2010 to items in this journal in 2009 and 2008 (896 + 1,227) by the number of substantive items listed in 2009 (214) and 2008 (233): 2,123/447 = 4.749. It means that an average article in *Arthritis Care and Research* is cited nearly 5 times within 2 years after its publication. Another leading journal in the same category *Seminars in Arthritis and Rheumatism* publishes mainly review articles. It has JIF 2010 almost equal to the previous one, 4.744. However, cites in the nominator of the JIF equation (427) and items in the denominator (90) are much smaller.

L. Bornmann
Max Planck Society, Administrative Headquarters, Munich, Germany

W. Marx
Max Planck Institute for Solid State Research, Stuttgart, Germany

A. Y. Gasparyan (✉) · G. D. Kitas
Clinical Research Unit, Dudley Group NHS Foundation Trust (A Teaching Trust of University of Birmingham), Department of Rheumatology, Russell's Hall Hospital, Dudley, West Midlands DY1 2HQ, UK
e-mail: a.gasparyan@gmail.com

G. D. Kitas
Arthritis Research UK Epidemiology Unit, University of Manchester, Manchester, UK

Along with the 2-year JIF, several other journal metrics have been proposed by JCR in an attempt to provide more comprehensive coverage of citations and objectivity towards slowly developing disciplines. A prime example is the 5-year JIF calculated in the same way as the 2-year JIF but within a 5-year time frame [4].

Inappropriate use of JIF for the evaluation of journal articles' scientific value

Research evaluation is increasingly based on citation analyses, and the easily retrieved JIF is more commonly used as a substitute for comprehensive research evaluation, particularly in Europe. Here, JIF is sometimes inappropriately used as a yardstick for measuring the scientific value of journal articles [7]. One should not forget that this specific scientometric product was proposed as a surrogate measure of a journal's quality, but never as an indicator of an individual's or an article's scientific merit [8, 9]. It is well known that JIF poorly correlates with citation rate of separate articles [10]. On the one hand, a high-quality article in a low- or medium-rank journal may attract more citations than a mediocre item in a high-rank journal with impressive JIF [11]. On the other hand, a few highly cited papers, particularly reviews published in one or a few issues, can boost a 2-year JIF and maintain its inflated value over the following 2-year period [12, 13]. A striking example is the 2-year JIF of *Acta Crystallographica A*, which reached 49.93 point in 2009 after a modest 2.38 level reported in the preceding 4 years [14].

One of the serious limitations of JIF is the uncertainty over the "citable" items counted in the denominator of its formula, which is open to debates and even "negotiations" between publishers and Thomson Scientific [15]. The inclusion of all citations to all types of publications, including letters, news items, book reviews and even errata in the numerator, but only citable items in the denominator, is not properly justified [16, 17]. For example, high-impact journals such as *Nature, Science, The New England Journal of Medicine* and *The Lancet* publish a large amount of news items, editorials and letters, excluded from the denominator of the JIF formula, but attracting numerous citations and potentially overestimating JIFs.

Another limitation is the short time frame of 2-year JIFs, reflecting the rise of citations in rapidly changing fields of science such as chemistry, toxicology, pharmacology and general medicine, but disadvantaging many other subject categories, where it usually takes more than 1 year to collect a wealth of citations (e.g. mathematics, social science and education) [18, 19]. Finally, JIFs are average indicators, ignoring level of total citations and publishing activity (for example, in the case of *Arthritis Care and Research* and *Seminars in Arthritis and Rheumatism* with equal values of JIF).

The obsession with 2-year JIF has substantially skewed publishing tendencies in the countries of emerging science or scientific periphery, where the quality of local journals suffers due to the citations of foreign articles to the expense of local ones and the authors' preferences to publish their best articles in higher JIF foreign journals [20, 21]. Apparently, citation rates and preferences most of the time are dependent on non-scientific reasons, questioning the reliability of the citation-based scientometric parameters [22]. Language, frequency of issuing and availability of publications, type of published articles, authors' gender, number of professionals in each field and typographical mistakes in reference lists may influence a journal's scientometric profile both ways (i.e. increase or decrease in JIFs) [22]. In fact, the differences in the size of professional communities, the numbers of their indexed journals and type of articles in different fields, and the researchers' differing citing behaviours make the common practice of comparing JIFs in different fields (e.g. chemistry vs. physics, cardiovascular medicine vs. rheumatology) and subfields (e.g. biomaterials vs. textiles, non-invasive cardiology vs. invasive cardiology) non-scientific and absolutely unacceptable.

Due to the concerns over the credibility of JIFs for measuring research quality and their disadvantaging effect on some, particularly highly specialised subject categories, research assessment and funding agencies in the UK repeatedly discouraged the "blind" use of JIF for research grant allocation and ranking academic institutions [23, 24]. Furthermore, the International Mathematical Union criticised the sole reliance on citation statistics in judging the quality of journals, individual articles and credentials of scientists, and warned against the use of 2-year JIF for ranking journals in slowly developing disciplines [25].

Obviously, when it comes to bibliometric analyses, average citation parameters in the form of 2- or 5-year JIFs should be complemented by a journal's total citation rate, individual article citation counts and some other criteria. In this regard, an independent expert opinion and acceptance of a journal, an article or a researcher by the scientific community should still be considered as crucially important factors [26, 27].

The effect of several journal versions on JIF

There are many journals available in different language versions aimed to attract a wider readership. For example, *Joint, Bone and Spine* and *Revue du Rhumatisme* are English and French editions of the same rheumatological journal, both indexed in Science Citation Index, but with different citation rates. The issue of citability of this and

similar journals and their impact is not fully explored. In the absence of proper analyses of how their JIFs are calculated, erroneous judgements over their scientometric profiles are inevitable. The case of *Angewandte Chemie* and *Angewandte Chemie—International Edition*, the German and English versions of the same journal, is a good example. Some authors cite articles in *Angewandte Chemie* with reference to both German and English versions, and double the citation rate and artificially inflate JIFs of the journal in JCR [28, 29]. By journal title matching procedure, i.e., by a JIF-specific method to determine citations to all papers of a given journal, citations to both editions of *Angewandte Chemie* were counted and a 15% overestimation of its JIF was found [29]. A similar overestimation is likely with other bilingual editions of indexed journals.

Another potential cause of JIF overestimation may arise with the implementation of the so-called green open access, a two-stage publication initiative, when both final peer-reviewed and published versions of the same manuscript appear in online databases and repositories of academic institutions. The project, aimed to accelerate publication of new scientific results, to provide more transparency and to evaluate a journals' viability, is supported by leading publishers such as Springer, Oxford University Press, Elsevier, Wiley-Blackwell and others [30]. In this regard, interesting is the recently investigated case of the interactive, open-access journal *Atmospheric Chemistry and Physics* with a relatively high rank in JCR in the category Meteorology and Atmospheric Sciences, employing the innovative two-stage publication format [31]. The process of peer review and publication in this journal differs from that in traditional scholarly journals [32]. The peer-reviewed items of *Atmospheric Chemistry and Physics* appear on its website as discussion papers, slightly different from the final publications. The publication of the two versions might inflate JIF because of counting final publications in the denominator of the JIF formula and citations to both versions in the numerator. Thomson Scientific, however, took that into account and included in the numerator citations to only one version of the journal, thus avoiding mistakes with calculation of the actual JIF [31]. This case is in contrast to the case of the bilingual journal *Angewandte Chemie*, where the fact of citations to the two versions of the same items was overlooked [29]. More investigations are pending to clarify the effects of multiple publications in other journals on JIF.

Additional metrics in JCR

Over the past decades, there have been many attempts to overcome limitations of the popular JIF and to propose new citation metrics bearing more comprehensive information on citable sources and their scientific value. The latter has become especially important in the age of digitisation and availability of numerous online databases widening prospects of scholarly communication and objective assessment of research output.

One of the significant achievements in the field of scientometrics is the proposition of metrics considering weight, or scientific prestige, of citations from different literature sources. One such proxy for evaluating scientific prestige is the Eigenfactor™, which takes into account the quantity and "quality" of citations, and employs the idea that citations from highly cited journals weigh more than those from less-cited ones [33]. It resembles the way of ranking web pages based on "weight" of hyperlinks to a web page and is calculated using an algorithm similar to Google's PageRank. An important advantage of the Eigenfactor over JIF is that it is not an average estimation of the impact. Notably, the Eigenfactor strongly correlates with JIF [34] and total citation counts and ranks *Nature*, *Proceedings of the National Academy of Sciences of the United States of America*, *Science*, and *the Journal of Biological Chemistry* among top scholarly journals [35].

Eigenfactor scores are now incorporated in JCR along with Article Influence™ scores. Article Influence scores are derived from Eigenfactor scores divided by citable items of a journal and normalised against the mean Article Influence score of 1.00. Importantly, both new metrics are based on a 5-year time frame and do not take into account journal self-citations [36].

Other additions to the JCR metrics are the immediacy index and the cited half-life. The immediacy index reflects how often, on average, journal articles are cited in the same year of publication. Apparently, journals with open access and frequent issues, widely visible in prestigious databases and covering rapidly evolving fields of science (e.g. molecular medicine, pharmacology) will have greater values of this metric [37, 38]. The cited half-life defines the number of years ("age") required to reach 50% of the total citations a journal. It reflects the period for which articles in a journal continue to attract citations [36]. In other words, the cited half-life provides information on how long articles are used by the scientific community and continue impacting science ("ageing").

Alternative impact factors

Limitations of JIFs and limited access to the JCR indicators prompted the search for alternative, more accessible and comprehensive impact factors. A major step forward was the proposition of SCImago Journal Rank (SJR) by SCImago research laboratory in Spain in 2007 [39, 40]. Similar to Eigenfactor, SJR is computed using Google's PageRank

algorithm and is based on the idea that citations from highly cited journals weigh more than those from low-cited ones. Importantly, a strong correlation exists between SJR and JIF [40]. SJR considers citations in Scopus database within a 3-year period. Scopus indexes more journals than Thomson Scientific, and SJR can be viewed as a more comprehensive indicator. Many, particularly newly launched, small and non-English journals listed in Scopus but not in Thomson Scientific may benefit from having an alternative impact factor such as SJR [41]. In fact, SJR values, freely available at the SCImago Journal and Country Rank website [42], are increasingly displayed on websites of many new journals. Relevant examples are Scopus-indexed *European Science Editing* and journals of the DovePress publishing house, where editors can use SJR as an indicator of citability of their publications and take measures to improve the journals' quality and visibility.

Dissimilar to JIF, the SJR formula ignores journal self-citations and contains in the denominator both citable and non-citable items, making the new indicator more objective and comprehensive [43]. Perhaps the main limitation of SJR is that it gives too much weight to citations from top-rank journals compared to those from medium- and low-rank journals [40]. The latter may have a diminishing effect on SJR values of journals receiving citations from new, small and low- to medium-rank journals. Conversely, it is possible to substantially increase values of SJR by increasing quality of journal articles and chances of citations coming from top journals.

Another indicator which can be viewed as an alternative to JIF is the journal *h*-index. Like SJR, it is an open-access metric, calculated using Scopus data, and freely available at the SCImago Journal and Country Rank website [42]. Google Scholar and Web of Science data can also be used to calculate the journal *h*-index [44], but with less accuracy in the former and with subscription-based access in the latter case. The journal *h*-index is calculated in the same way as the originally proposed by Jorge Hirsch an individual scientist's *h*-index [45], i.e., the least number of publications (*h*), each of which is cited at least *h* times. The journal *h*-index can take into account the list of publications over one or more years [46]. It strongly correlates with JIF and distinguishes biomedical journals as relatively highly cited [46]. In fact, the new indicator bears information on the number of highly cited articles, which is important for comprehensive assessment of a journal's scientometric profile [47]. This is why some editors display the *h*-index value along with JIF on their journal's website [48].

The *h*-index is dependent on a journal's "age", its visibility and citability of the articles. Exemplary are rheumatology journals indexed by Scopus and Thomson Reuters (Table 1). The majority of these journals have substantially increased their JIFs in the past decade mainly because of

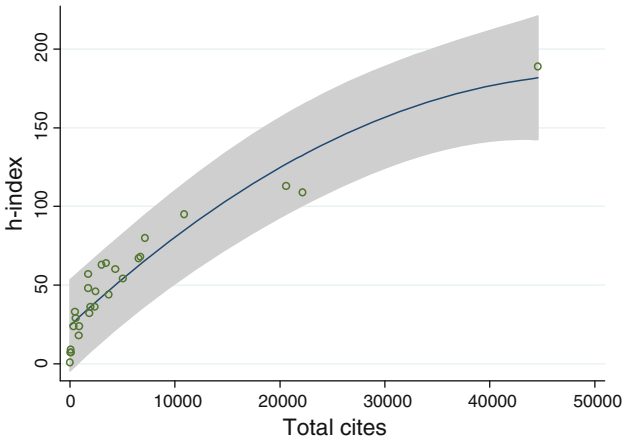

Fig. 1 Correlation between the *h*-index and total cites of the indexed rheumatology journals (Spearman rank correlation coefficient $r = 0.93$; $P < 0.05$)

continued interest towards this leading clinical discipline, raise of the number of review articles and some other reasons [49]. Of 29 journals presented in Table 1, only four have exceedingly high values of the *h*-index: *Arthritis and Rheumatism* (189), *The Journal of Rheumatology* (113), *Annals of the Rheumatic Disease* (109) and *Rheumatology* (95). These four are old, traditional journals, publishing predominantly recommendations, results of randomised controlled trials on emerging biological treatments, large cohort studies and systematic reviews; low-citable items (i.e. brief communications and clinical case studies) have low priority in these journals. By contrast, the majority of medium- and low-rank rheumatology journals publish a large amount of small original and case studies, and a few systematic reviews. Not unexpectedly, the *h*-index strongly correlates with total citation rate ($r = 0.93$; Fig. 1). A strong association also exists between the *h*-index and JIFs (Figs. 2, 3), which may prompt editors of rheumatology journals not covered by WoS to stick to the *h*-index as an alternative informative indicator.

As with other bibliometrics, the journal *h*-index should be used for comparisons within, but not between subject categories [50]. It has limitations inherent to the journal self-citations and editors manipulations by decreasing number of non-citable items and increasing review articles. It disadvantages new journals and lacks sensitivity to citation changes in journals with high values of *h*-index [44]. Besides, it does not reflect the number of exceedingly cited items, which may be crucial for comparing scientific prestige of journals with similar JIFs and *h*-index.

Limitations of the *h*-index can be overcome by corrections for active years, number of highly cited papers and switching to its variants [44], applicable as both individual and journal metrics. However, a previous own empirical analysis of twenty organic chemistry journals revealed a

Table 1 Scientometric profile of the Scopus- and Thomson Scientific-indexed rheumatology journals based on the *h*-index, total cites and JIFs

Rank based on 2-YIF	Title	The *h*-index	Total cites	2-Y IF	5-Y IF
1	*Annals of the Rheumatic Diseases*	109	22,172	9.082	7.551
2	*Arthritis and Rheumatism*	189	44,602	8.435	8.579
4	*Nature Reviews. Rheumatology*	33	468	6.448	6.466
5	*Arthritis Care and Research*	67	6,539	4.749	4.561
6	*Seminars in Arthritis and Rheumatism*	63	3,012	4.744	4.536
7	*Current Opinion in Rheumatology*	64	3,431	4.497	4.300
8	*Arthritis Research and Therapy*	68	6,728	4.357	4.798
9	*Rheumatology (Oxford)*	95	10,875	4.171	4.328
10	*Osteoarthritis and Cartilage*	80	7,138	3.953	4.495
11	*The Journal of Rheumatology*	113	20,578	3.551	3.573
12	*Best Practice and Research in Clinical Rheumatology*	48	1,707	3.300	3.486
13	*Rheumatic Disease Clinics of North America*	57	1,728	3.018	2.678
14	*Lupus*	60	4,325	2.600	2.565
15	*Scandinavian Journal of Rheumatology*	46	2,445	2.594	2.377
16	*Joint Bone Spine*	36	1,947	2.460	2.359
17	*Clinical and Experimental Rheumatology*	54	5,012	2.358	2.383
18	*BMC Musculoskeletal Disorders*	32	1,838	1.941	2.375
19	*Modern Rheumatology*	18	841	1.800	
20	*Clinical Rheumatology*	44	3,687	1.687	1.671
21	*Rheumatology International*	36	2,386	1.431	1.473
22	*Journal of Clinical Rheumatology*	24	850	1.283	1.324
23	*Journal of Musculoskeletal Pain*	24	316	0.460	0.516
24	*Acta Reumatologica Portuguesa*	7	113	0.451	
25	*Zeitschrift fur Rheumatologie*	29	522	0.447	0.437
26	*Aktuelle Rheumatologie*	9	74	0.243	0.140
27	*International Journal of Rheumatic Diseases*	7	35	0.205	
29	*Turkish Journal of Rheumatology*	1	8	0.043	0.103

Data obtained from SCImago Journal and Country Rank database (the journal *h*-index values in 2011) and JCR (total cites, 2- and 5-year journal impact factors [JIF] published by Thomson Scientific in 2011)

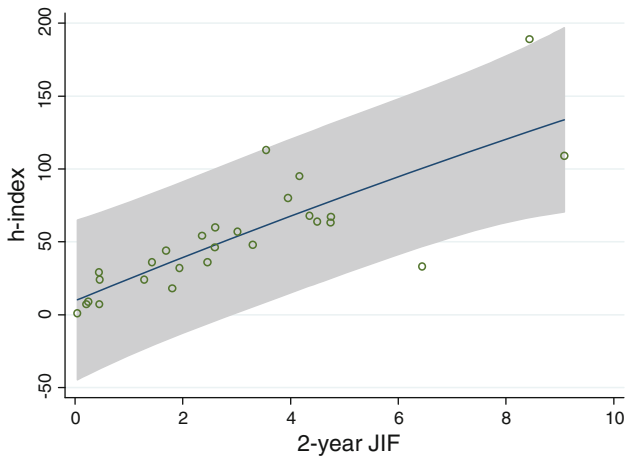

Fig. 2 Correlation between the *h*-index and 2-year JIF of the indexed rheumatology journals (Spearman rank correlation coefficient $r = 0.82$; $P < 0.05$)

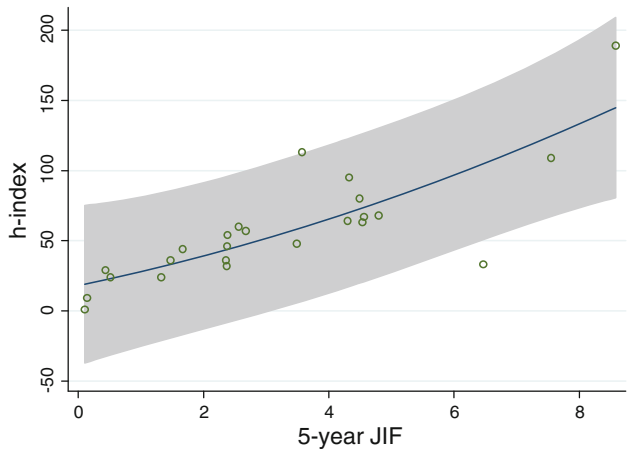

Fig. 3 Correlation between the *h*-index and 5-year JIF of the indexed rheumatology journals (Spearman rank correlation coefficient $r = 0.84$; $P < 0.05$)

similar positive correlation between *h*-index, its different variants and JIF, indicating redundancy of information supplied by the *h*-index variants [51].

Conclusion

Over the past decade, bibliometric tools to evaluate research productivity of individuals, academic groups, countries and scholarly journals have mushroomed. Research assessment agencies worldwide are now increasingly relying on citation-based indicators. Not surprisingly, preference is given to easily understood metrics such as JIF and the *h*-index, both of which can provide complementary information and can guide authors for choosing their target journals and science editors for improving prestige of their publications [41, 52, 53]. Numerous investigations have proved viability and, at the same time, revealed many limitations of both landmark indicators. The interpretation of their values is valid within but not between certain journal sets or subject categories. It is strongly discouraged to use JIF as a proxy of an individual researcher's or a journal article's scientific merits. Though average citation metrics such as JIF, the immediacy index and Article Influence score are increasingly popular, it is advised to look closely at journals' citation distributions and to analyse citations more comprehensively. Albert Einstein once pointed out that "we can't solve problems by using the same kind of thinking we used when we created them" [54]. The quote is also applicable to the bibliometric indicators discussed above. JIF should not be used as a sole measure of a journal rank. Its limitations can be overcome by complementing it with new alternative tools.

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