IEEE Access
Multidisciplinary ⁝ Rapid Review ⁝ Open Access Journal

Received September 22, 2017, accepted October 5, 2017, date of publication October 9, 2017, date of current version November 7, 2017.

Digital Object Identifier 10.1109/ACCESS.2017.2761400

Citation-Based Journal Rankings: Key Questions, Metrics, and Data Sources

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This work was supported in part by Manhattan College, in part by Menlo College, in part by Harris Manchester College, and in part by Oxford University.

ABSTRACT This guide presents nine key questions that can help researchers make good use of citation-based journal rankings (metrics) in the natural and social sciences. The nine questions address the characteristics that distinguish one metric from another: the source documents, the citation-counting window, the document types counted, the cited-document window, the impact of highly cited documents, the treatment of self-citations, the distinction between size-dependent and size-independent metrics, the use of normalization to account for disciplinary differences in impact, and the use of weighting to account for the impact or centrality of each citing journal. Next, the guide reviews 19 standard citation metrics, including the *h* index, *g* index, impact factor, source normalized impact per paper, eigenfactor, article influence score, and SCImago journal rank. Three underlying data sources (Web of Science, Scopus, and Google Scholar) are described, along with six major data download sites: Journal Citation Reports, Eigenfactor, CWTS Journal Indicators, SCImago, Scopus Journal Metrics, Cabell's International, and Google Scholar Metrics. The paper summarizes the main criticisms of citation metrics and concludes with suggestions for their further development, dissemination, and use.

INDEX TERMS Impact, indicator, metric, ranking, rating.

I. INTRODUCTION

Citation data have been used in the evaluation of scholarly journals since 1927, when chemistry faculty at Pomona College ranked 28 journals based on the number of times they had been cited in the *Journal of the American Chemical Society* [1]–[3]. Journal citation metrics entered the mainstream of scientific work about three decades later with the development of Science Citation Index (SCI) and the impact factor (IF) [4]. Indicators such as IF are now widely used by several groups: scholars seeking guidance about the journals most likely to publish important findings; authors seeking to maximize the impact of their research or to present their work in the best light; committees evaluating the scholarly contributions of faculty; accreditors and funding agencies assessing the work of departments and institutions; editors seeking to demonstrate the impact of their journals; librarians evaluating collections or making selection decisions; and researchers studying topics such as the development of emerging subfields or the impact of Open Access funding policies [3], [5]–[11].

This guide to citation-based journal rankings (citation metrics) is intended for each of these groups, and for scholars in related areas of information science who are new to bibliometric research. Specifically, the paper presents

- Nine key questions that can be used to characterize the citation metrics that have emerged since 1965—questions that ought to be considered by those who develop or use journal rankings (Section II)
- Nineteen standard citation metrics that are readily available online: total citations, total citations (three years), percent cited, *h* index, *h5* index, *h5* median, *g* index, IF, IF without self-citations, citations per document (two years), five-year impact factor (5IF), CiteScore, impact per publication (IPP), Cabell's classification index (CCI), source normalized impact per paper (SNIP), eigenfactor (EF), normalized EF (EFn), article influence score (AI), and SCImago journal rank (SJR) (Section III)
- Three primary sources of citation data—Web of Science (WoS), Scopus, and Google Scholar (GS)—and seven data download sites: Journal Citation Reports (JCR), the Eigenfactor site (EF), CWTS Journal Indicators, SCImago Journal & country Rank, Scopus Journal Metrics (SJM), Cabell's International, and Google Scholar Metrics (GSM) (Section IV)
- An overview of the most common criticisms of citation metrics (Section V).

None of the metrics presented here are specific to engineering, but all have proven useful in a wide range of natural and social science disciplines. Many key studies deal with the literature of fields such as economics and business, but their findings are often applicable to the physical sciences as well.

Journal rankings based on survey results or use statistics (e.g., download statistics compiled by libraries or publishers) are not covered here. Walters [12] presents an overview of survey-based journal rankings, and several important papers on use statistics have appeared in recent years [13]–[17]. Although indicators that measure web and social media activity (altmetrics) show promise, none have been widely accepted as substitutes for well-established measures of reputation and impact [18]–[24].

II. KEY QUESTIONS

Table 1 shows 18 of the 19 citation metrics that are publicly available online. (It also lists the standard abbreviations for the metrics and data sources.) Another key metric, the *g* index, is described in Section III.B.

The columns of Table 1 represent some, but not all, of the major distinctions among the various metrics. Table 2 provides more insight into those distinctions. Specifically, it presents nine key questions that represent the choices involved in the development of a citation metric. Together, the nine questions can be used to categorize nearly all the citation metrics that have been developed since 1965.

Arguably, the typology presented in Table 2 is more comprehensive than those set forth in earlier studies. For instance, Waltman [25] identifies just five basic citation impact indicators in two categories: size-dependent (total number of citations, number of highly cited publications, and the *h* index) and size-independent (average number of citations per publication and the proportion of highly cited publications). Looking more broadly at both revealed preference indicators (those based on actual behaviors, such as publishing or citing) and stated preference indicators (those based on opinion surveys), Banks and Dellavalle [26] present five alternatives to the impact factor: metrics closely related to IF, metrics that also account for the importance of each citing journal, nonlocal use statistics such as the number of downloads per article, recommender systems based on expert assessments, and measures based on inputs into the scholarly communication system. Likewise, Morris *et al.* [27] describe four approaches to journal ranking: citation studies, peer surveys, institutional lists, and derived lists (those based on data gathered for other purposes).[1]

Although there are substantial differences among the various citation metrics, every one of them represents scholarly impact (citedness), either generally or within a particular discipline. A central question in the development of *survey-based* journal rankings—"What construct is being measured? Is it reputation? Influence? Utility?"—is not a major issue where citation metrics are concerned.

A. WHAT ARE THE SOURCE DOCUMENTS IN WHICH THE CITATIONS APPEAR?

An early step in the development of any citation metric is to identify the source documents from which citations will be compiled or counted. Although the most common practice is to count the citations that appear in particular journals, there is no reason why other scholarly works cannot be used as source documents. For instance, Urbancic [34] identified the top international business journals by counting the number of times they were cited within 26 textbooks. Liner [35] used a similar procedure to rank the top economics journals. Although the use of textbooks as source documents is not widespread, one can argue that the journals most often cited in textbooks have met an especially high standard; they have published the theories, methods, and findings worthy of being passed on to future generations of educated individuals. Books, including textbooks, may also be especially important as vehicles for the transmission of academic knowledge to practitioners [36].

Reading lists and dissertations have also been used as source documents. Skeels and Taylor [37] ranked 35 economics journals based on the number of times they appeared in the graduate reading lists published in *The American Economist* over a nine-year period. Likewise, Chan *et al.* [38] ranked 42 accounting journals based on the number of times they were cited in doctoral theses. This same technique can be used with the works produced by the faculty or students at particular institutions [39]–[42].

Table 2 makes a distinction between metrics that draw citations from a small number of journals and those that draw citations from a large number of journals. The difference lies not in the adequacy of sampling, but in the intention of the metrics' developers. In some cases, the source documents are intended to represent the entire discipline (or disciplines), while in others they are intended to represent only the journals that are special in some way (i.e., those most closely associated with Marxian economics).

We can further distinguish between those metrics that represent each journal's impact on a particular discipline (those for which the source journals are all in one field) and those that represent each journal's impact on the scholarly literature as a whole [3]. The distinction between disciplinary impact and overall impact is important. For example, He and Pao [43] ranked 146 veterinary journals based on their citation impact (a) within a set of 74 veterinary journals and (b) within the scholarly literature as a whole. They found that citation impact within the field of veterinary medicine is unrelated to overall impact ($r = -0.02$, $p > 0.80$). This suggests that there may be a disconnect between clinical utility and scientific importance.

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[1] These typologies are complemented by three recent guides to citation metrics [25], [28], [29]. All three focus on the assessment of individuals and institutions rather than journals, however. Setti [30] reviews several current issues in the bibliometric literature but discusses only a selection of the most widely used indicators. Although brief guides to journal rankings are not difficult to find [31]–[33], most of them offer only limited contextual information and detail.

TABLE 1. **Citation metrics available at seven data sites.**

Metric	Data download site	Citation-counting window	Docs. for which citations are counted	Cited-doc. window	Self-citations included?	Size-dependent?	Docs. that contrib. to the article count	Normalized?[a]	Weighted?[b]
Total citations	JCR	1 yr.	All	All yrs.	Yes	Yes	—	No	No
Total citations (3 yrs.)[c]	SCImago, SJM	1 yr.	All	3 yrs.	Yes	Yes	—	No	No
Percent cited	SJM	1 yr.	All	3 yrs.	Yes	No	All	No	No
h index	SCImago	Varies	N.A.	Varies	Yes	Yes	—	No	No
h5 index	GSM	—	All	5 yrs.	Yes	Yes	—	No	No
h5 median	GSM	—	All	5 yrs.	Yes	Yes	—	No	No
IF (impact factor)	JCR, Cabell's	1 yr.	All	2 yrs.	Yes	No	Citable	No	No
IF without self-citations	JCR	1 yr.	All	2 yrs.	No	No	Citable	No	No
Citations per doc. (2 yrs.)	SCImago	1 yr.	N.A.	2 yrs.	Yes	No	N.A.	No	No
5IF (5-yr. impact factor)	JCR	1 yr.	All	5 yrs.	Yes	No	Citable	No	No
CiteScore	SJM	1 yr.	All	3 yrs.	Yes	No	All	No	No
IPP (impact per publicatn.)	CWTS	1 yr.	Citable	3 yrs.	Yes	No	Citable	No	No
CCI (Cabell's class. index)	Cabell's	3 yrs.	N.A.	N.A.	Yes	No	N.A.	Yes	No
SNIP[d]	CWTS, SJM	1 yr.	Citable	3 yrs.	Yes	No	Citable	Yes	No
EF (eigenfactor)	JCR, EF	1 yr.	All	5 yrs.	No	Yes	—	Yes	Yes
EFn (normalized EF)	JCR, EF	1 yr.	All	5 yrs.	No	Yes	—	Yes	Yes
AI (article influence score)	JCR, EF	1 yr.	All	5 yrs.	No	No	Citable	Yes	Yes
SJR (SCImago jnl. rank)	SCImago, SJM	1 yr.	Citable	3 yrs.	Yes[e]	No	Citable	Yes	Yes

The seven data sites are shown in Tables 3 and 4. See Section III.B for the *g* index, an important citation metric not available from those sites. Simple transformations of the basic metrics (e.g., percentile scores) are not listed here. *Citable* items are those counted as citable items by Web of Science and Scopus—original articles, review articles, and conference proceedings. N.A.: data not available.

[a] Normalized to account for disciplinary differences in citation impact?

[b] Weighted to account for the impact of each citing journal?

[c] Total citations (3 yrs.) is called *citn. count* in SJM.

[d] Source normalized impact per paper.

[e] Limited to one-third of the citations.

Finally, the source documents need not represent *all* the items published in the journals of interest. It is possible to rank journals based on the number of times they have been cited within the articles that focus on a particular subfield, for instance [44]. This approach is especially appropriate for disciplines with well-established subject classifications such as economics, mathematics, and medicine. Likewise, we can limit the source documents to the most highly cited

TABLE 2. A categorization of citation-based journal ranking metrics.

- What are the source documents in which the citations appear? (Section II.A)
    - Document type
        - Textbooks
        - Reading lists
        - Dissertations
        - Small number of journals
            - Prestigious or high-impact journals
            - Journals notable for other reasons
        - Large number of journals
        - Sets of relevant articles not from particular journals
    - Disciplinary scope
        - Multidisciplinary
        - A particular field of study (e.g., economics)
        - A particular subfield (e.g., labor economics)
    - Geographical scope
        - International
        - Regional (e.g., Southeast Asia)
        - National
        - Sub-national (e.g., Francophone Canada)

- How long is the citation-counting window? (Section II.B)

- For what types of documents are citations counted? (Section II.C)
    - All items (including editorials, feature columns, book reviews, etc.)
    - "Citable items" (e.g., original articles and review articles)

- How long is the cited-document window? (Section II.D)

- What is counted—citations or highly cited documents? (Section II.E)
    - Number of times the source documents were cited
    - Number of highly cited documents
        - Threshold level is specified
        - Threshold level varies, as with the *h* index

- Are self-citations included? (Section II.F)
    - All are included
    - Some are included
    - None are included

- Is the metric influenced by the size of each journal? (Section II.G)
    - Yes; it is size-dependent—a "whole journal" metric
    - No; it is size-independent—a "typical article" metric
        - What is the summary statistic?
            - Mean
                - Denominator is the number of documents
                    - All items
                    - "Citable items"
                - Denominator is the number of pages, words or characters
            - Median

- Is the metric normalized to account for disciplinary differences in citation impact? (Section II.H)
    - No
    - Yes
        - Using target normalization
        - Using source normalization
        - Using influence measures (recursive algorithms)

- Does the metric account for the impact or centrality of each citing journal? (Section II.I)
    - No
    - Yes

papers, thereby evaluating the influence of each journal on the discipline's most important research contributions [45].

B. HOW LONG IS THE CITATION-COUNTING WINDOW?

The citation-counting window is the timespan for which citations are counted. It refers not to the publication dates of the cited documents, but to the dates of the *citing* documents (source documents).

For most metrics, the citation-counting window is a single year. (See Table 1.) That is, the citations counted are those that appeared in the reference lists of the documents (e.g., articles) published in one particular year—the report year. The *report year* is the most recent year for which complete citation data are available.

C. FOR WHAT TYPES OF DOCUMENTS ARE CITATIONS COUNTED?

Nearly all citation metrics count the citations that appear within the reference lists of the designated source documents. With some metrics, every citation is counted, whether the cited item is an empirical study, a review article, an editorial, a letter, an erratum, an announcement, or a book review. Other metrics count only citations to ''citable items'' as defined by the data providers: original articles, review articles, and (for metrics based on Scopus data) conference proceedings. Of course other types of content may actually be cited, but metrics such as SJR disregard citations of ''non-citable'' items on the assumption that those citations do not represent real scholarly impact [46].

D. HOW LONG IS THE CITED-DOCUMENT WINDOW?

The cited-document window refers to the publication dates of the cited documents. It is therefore distinct from the citation-counting window (Section II.B), which refers to the dates of the citing documents (source documents).

For most citation metrics, the cited documents include only those papers published within the past two, three, or five years; no attempt is made to count citations to items published in earlier years. The cited-document window is therefore two, three, or five years. The window varies with each indicator, however, and it may or may not include the report year. For instance, the *total citations (3 years)* metric represents the number of times the articles published in the journal over a three-year period (the three years prior to the report year) were cited during the report year.

Several authors have argued that the cited-document windows of many citation metrics are too short to accurately represent journal impact in fields where citations accrue only slowly [47]–[50]. These concerns have led to the use of longer cited-document windows for newer metrics such as 5IF, IPP, SNIP, AI, and SJR. (See Table 1.) However, van Leeuwen [51] has shown that for biochemistry, economics, information science, mathematics, and pathology, the use of a longer window has little impact on IF values.

E. WHAT IS COUNTED—CITATIONS OR HIGHLY CITED DOCUMENTS?

Most citation metrics count citations. That is, each additional citation brings an increase in impact (i.e., an increase in the citation statistic or its numerator). However, other metrics are based on the number of highly cited documents—those that meet a specified threshold level. For instance, it is possible to rank the top biomedical journals by counting the number of highly cited articles that have appeared in each journal [52]. The threshold level ("highly cited") may be either fixed or variable. For instance, the *h* index uses a variable threshold level; it represents the number of articles (h) that have each received at least h citations [53]. A journal with an h index of 80 has published 80 articles that have each been cited at least 80 times.

F. ARE SELF-CITATIONS EXCLUDED?

Citation metrics vary in their treatment of journal self-citations—instances in which the cited work was published in the same journal as the citing work. Some indicators include these self-citations. Others exclude them, and still others limit the extent to which they can contribute to each journal's citation count. The exclusion of self-citations seems unreasonable if we assume that every citation is legitimate. However, a high rate of journal self-citation may indicate that the editors or reviewers encourage this practice in order to inflate their journal's impact [47], [50], [54]–[58]. Journal self-citation rates as high as 85% have been reported [59].

These concerns may be overstated, however. Several citation metrics do exclude self-citations, either fully or partially (Table 1), and many data providers incorporate provisions for the investigation of journals with anomalous patterns of self-citation [60]. The journal with an 85% self-citation rate was removed from JCR, for instance [59]. Moreover, the available evidence suggests that differences in self-citation rates have only a modest impact on most journal rankings [61]. For instance, Nisonger [62] adjusted the impact factors of 74 genetics journals and 59 information science journals to exclude self-citations, then reported the correlations between the original IFs (which include self-citations) and the adjusted IFs (which do not); $r = 0.997$ (genetics) and 0.94 (information science). His adjustments changed the ranks of the journals by an average of just one position (genetics) or just three positions (information science). Overly strict policies against the counting of self-citations may also be unfair to authors and editors in specialized areas where there are only a few outlets for important new work.

G. IS THE METRIC INFLUENCED BY THE SIZE OF EACH JOURNAL?

A fundamental distinction can be made between size-dependent and size-independent metrics. Size-dependent (*whole journal*) metrics represent the impact of the entire journal and can be expected to increase or decrease in response to changes in the number of articles published. In contrast, size-independent metrics represent the impact of a typical article and do not vary in response to changes in the number of articles that appear in each journal. Size-dependent and size-independent metrics tend to have dissimilar values, and the distinction between the two has important implications for their use [3], [33], [63]. A librarian evaluating the cost effectiveness of journal subscriptions is likely to be interested in size-dependent metrics, since the overall value of each journal is influenced by the number of articles it publishes as well as the expected impact of each article. In contrast, an author deciding where to send his or her paper may be more interested in size-independent metrics.

Size-independent metrics can be further categorized based on the ways in which they account for journal size. (See Table 2). Nearly all such metrics are means, in which the total impact of the journal is divided by the number of articles published. However, the mean may misrepresent the impact of a typical article when the distribution of citations is skewed. Although several authors have advocated for the use of medians rather than means in the calculation of citation metrics, no median-based metric is in general use, perhaps because such indicators are difficult to integrate into a broader statistical framework [55], [64], [65]. They may pose mathematical difficulties when used as components of other statistics, for instance, and they are not easy to adjust in response to factors such as disciplinary differences in citation impact.

As noted in Section II.C, some citation metrics count all citations while others count only citations to "citable items."[2] A parallel situation arises when counting the number of articles in each journal. We might expect that any restrictions applied to the numerator of a size-independent metric (i.e., the documents for which citations are counted) would apply equally to the denominator (the documents counted in the calculation of journal size). Several metrics conform to this expectation, although others, such as IF, have been criticized for including citations to all items in the numerator while counting just citable items in the denominator—a practice that carries the potential for editorial manipulation [50], [66], [67]. Fortunately, variations in the percentage of non-citable items appear to have only a negligible effect on IF within the fields of engineering, medicine, and multidisciplinary science [68].

While it is usual to express the size of each journal as the number of articles published, there are other possibilities as well. In their ranking of management journals, Sharplin and Mabry [69] controlled for journal size by counting the number of citations per 10,000 words. Likewise, Scott and Mitias [70] counted pages rather than articles when ranking the productivity of American economics departments. Liebowitz and Palmer [71] ranked economics journals by calculating a statistic similar to IF, but with journal size expressed as the number of characters per year. By controlling for article length, they ensured that journals with relatively many short papers were not at a disadvantage in comparison with those that published only full-length articles.

H. IS THE METRIC NORMALIZED TO ACCOUNT FOR DISCIPLINARY DIFFERENCES IN CITATION IMPACT?

Citation rates vary substantially by discipline. Papers in biochemistry, for instance, tend to be cited far more than those in

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[2] Henceforth, the phrase "citable items" refers to those document types that are counted as citable items by Web of Science and Scopus—original articles, review articles, and conference proceedings. Of course the "citable items" category does not actually include all the items that might be cited.

political science and mathematics [72]. In fact, the sociology journal with the highest impact factor, *American Sociological Review*, has an IF similar to that of a mid-level cell biology journal. Because of these disciplinary differences, it is not usually appropriate to compare unadjusted citation scores across fields [73]–[76]. There are exceptions to this general rule, however. For instance, scholars working in interdisciplinary areas may care more about overall citation impact than about the reception of their work within any particular field [77].

As Table 1 shows, several of the newer citation metrics are adjusted (normalized) to account for disciplinary differences in citation impact. However, the rationale for normalization is not always clearly stated. Three observations may help put normalized metrics into perspective:

- Normalization is based on the assumption that the various fields simply differ in their average citation impact or in the rate at which citations accrue—not in authors' reasons for citing or in the inherent meaning of a citation. As Zitt [78, p. 496] has pointed out, normalization is consistent with the view that "some disciplines produce big apples, others small apples." Normalization is less appropriate "if one discipline produces apples and the other oranges."
- Although normalization is intended to control for differences in citation rates among fields, the standard field-normalized citation metrics—SJR, SNIP, and AI—do not actually eliminate disciplinary differences in impact. The average SJR value for life science journals (0.31) is much higher than that for social science journals (0.05), and a similar relationship can be seen for SNIP [79]. Likewise, academic disciplines vary considerably in their AI scores [80]–[82]. The average AI score for developmental biology is 1.83; for social work, 0.43.
- We can also compare the relative influence of journals within their disciplines in a more straightforward way, simply by converting each unadjusted citation score to a percentile rank or a standardized score [73]. Neither conversion is difficult, and both allow for inter-field comparisons. ("*Water Resources Research* is 0.58 SD above the mean in environmental science; *Water Resources Management* is 1.28 SD above the mean in civil engineering.")

These three observations suggest that the goal of normalization is not simply to facilitate comparisons of relative impact across disciplines, but to make citation impact scores more nearly comparable *through a method that is conceptually and statistically grounded*. For instance, the normalization method used by Moed [83] to construct the SNIP metric is rooted in Garfield's [73] notion of citation potential—the average number of references appearing in the bibliographies of the papers in a particular subject area. Garfield's recommendation, adopted by Moed and others, is to weight each journal's citation count in inverse proportion to the number of references found within the cited journals of the relevant discipline. A citation in a field with relatively few citations will therefore count for more than a citation in a field with relatively many citations. This method has been described as *source normalization* or *citing-side normalization* [83], [84].

An alternative approach, *target normalization* or *cited-side normalization*, is based not on the number of references found within the journals of a discipline, but on the number of times those journals have been cited [83], [85]. If each subject area were independent—if academic disciplines did not export or import citations to/from other fields—then source normalization and target normalization would yield the same results. The two methods produce somewhat different results, however, since disciplines vary in the extent to which they export and import citations [86].

A third method of normalization was introduced with metrics such as EF, AI, and SJR, which have been described as *influence measures* [78] and as *recursive citation impact indicators* [25], [87]. These metrics make use of influence weights similar to those proposed by Pinski and Narin [88]; they simultaneously adjust each journal's score to account for (a) field-related differences in citation rates and (b) the impact or centrality of each citing journal. With influence measures, the characteristics of both citing and cited journals are taken into account.

I. DOES THE METRIC ACCOUNT FOR THE IMPACT OR CENTRALITY OF EACH CITING JOURNAL?

Most citation metrics simply count citations, weighting each one equally. A citation in *Nature*, for instance, is assigned no more weight than a citation in a regional subspecialty journal. However, several of the newer citation metrics—EF, AI, and SJR, in particular—are weighted so that citations in high-impact journals (or those that are more centrally located within the citation network) count for more than citations in lower-impact journals.[3]

Pinski and Narin [88], building on a suggestion made by Kochen [93], were the first authors to demonstrate how this idea can be put into practice. Using data for 103 journals in nine subfields of physics, they developed a set of citation metrics weighted to reflect the influence of each citing journal. Subsequent research led to the *p*-rank metric, which can be used to rank articles, authors, or journals [92], [94]. Citation metrics can also be weighted according to the citing journal's influence *within a particular field of study*. For example, Liebowitz and Palmer [71] calculated a statistic similar to IF, but weighted it to reflect the influence of each citing journal within the field of economics. (Citations in non-economics journals were not counted at all.) Laband and Piette [95] undertook a similar analysis based on the citations found in economics journals in 1970, 1980, and 1990. In both studies, the weighting procedure led to higher ratings for the foremost

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[3] Several authors have argued that unweighted metrics such as IF represent popularity (endorsements from a broad population) while weighted metrics such as AI and SJR represent prestige (endorsements from experts or elites) [89]–[92]. This assertion has not been tested empirically, however [63].

core journals but to lower ratings for less prestigious and more specialized journals.

The first weighted citation metrics to achieve widespread use were EF and AI [96]. Both make use of a recursive algorithm that evaluates the centrality of each journal within the citation network. Essentially, they account for the citation impact of the journals that cite a particular paper, the citation impact of the journals that cite *that* journal, and so on. A similar approach was used by Zhang *et al.* [97] in the development of their quality-structure index (QSI). All else equal, a more central place within the citation network results in a higher QSI score.

III. STANDARD CITATION METRICS

As noted in Section II, Table 1 shows the standard citation metrics that are publicly available online. Except for the *h* index, the *h5* index, and the *g* index, each is based on a count of citations rather than a count of highly cited documents. Moreover, each of the size-independent metrics is a mean rather than a median, with the number of citations in the numerator and the number of documents (or citable documents) in the denominator.

As the horizontal lines in Table 1 suggest, the metrics can be placed into six groups (Sections III.A to III.F, below). These groups are based primarily on the characteristics shown in Tables 1 and 2, but they also account for the historical origins of each metric.

A. SIMPLE CITATION COUNTS

The simplest citation metrics are citation counts. Two citation-count metrics are readily available.

- *Total citations* is the number of times the articles published in the journal (all years) were cited during the report year.
- *Total citations (3 years)* is the number of times the articles published in the journal over a three-year period (the three years prior to the report year) were cited during the report year.

Both these metrics are size-dependent; they will be higher, all else equal, for journals that publish more articles per year. A related measure, *percent cited*, is the percentage of articles published in the three years prior to the report year that were cited during the report year. Because the numerator and the denominator vary proportionally in response to journal size, *percent cited* is a size-independent metric.

B. *h* INDEX, *h5* INDEX, *h5* MEDIAN, AND *g* INDEX

The *h* index was developed by Hirsch [53] at the University of California, San Diego, and introduced in 2005. Initially applied to individual scholars, it has since been used to evaluate journals. Because the *h* index is a size-dependent metric, it represents the impact of the journal as a whole—not the impact of a typical article.

Two data sites, SCImago and GSM, provide access to three *h*-index metrics.

- *h index* is the number of articles (*h*) published in the journal (all years combined) that have each been cited at least *h* times. For example, a journal with an *h* index of 80 has published 80 articles that meet the ‘‘80 or more citations’’ threshold.
- *h5 index* is the number of articles (*h*) published in the report year and the preceding four years that have each been cited at least *h* times.
- *h5 median* is the median number of citations (in the report year and the preceding four years) to those articles that have each been cited at least *h* times.

Although the *h5* index is based on five years' data, the SCImago *h* index is based on all the data available in the Scopus database. The SCImago *h* index for any particular journal therefore depends on the date of its founding as well as the extent of its coverage in Scopus. (For journals with complete data, the SCImago *h* index covers 1996 to the current year.)

Unlike the other metrics shown in Table 1, *h* and *h5* account only for the number of highly cited articles in each journal. Two journals, each with an *h* index of 80, may be considerably different in citations per article and in the distribution of articles with fewer than 80 citations. An *h* index of 80 tells us nothing about the impact of the articles that were cited fewer than 80 times. Likewise, the *h* index is not influenced by changes in the citation counts of papers that have been cited at least *h* times.

The *h* index is also distinctive because its value can only increase, never decrease, over time. As Egghe [98, p. 8] has noted, new researchers (and, by extension, new journals) are at a disadvantage due to their relatively short publishing careers. In contrast, established scholars and journals ‘‘may rest on their laurels since the number of citations received may increase even if no new papers are published.’’ Hirsch [53] has suggested dividing the *h* index by the number of years since first publication to allow the comparison of authors (and journals) with publication records of varying lengths.

The *h* index is not normalized to account for differences in citation rates among disciplines. Iglesias and Pecharromán [99] have described how such an adjustment can be made, but their approach has not been widely adopted. The *h* index also counts each citation equally; citations in high-impact journals are assigned no more weight than those in low-impact journals.

Waltman and van Eck [100] have drawn attention to several inconsistencies in the *h* index. In particular, they note that equal improvements in citation performance can produce unequal changes in relative ranking, and that the rank-order of aggregates (e.g., research groups or journals) does not always correspond to the rank-order of the individual authors or papers that make up those aggregates.

A variant of the *h* index, the *g* index, was developed by Leo Egghe of Hasselt University in 2006. Unlike the *h* index, the *g* index does account for the number of citations received by papers with more than *h* citations. Specifically, *g* is the largest number for which an author's (or journal's) g most cited articles together received at least g^2 citations [101], [102]. As might be expected, authors (and journals) that publish a few stellar works plus a modest number of additional papers tend to have high g values relative to their h values. In contrast, those that publish relatively many papers but few stellar contributions tend to have high h values relative to their g values [103]. Like the h index, the g index has been used to evaluate journals as well as Rosenstreich and Wooliscroft [104], [105] and Serenko and Bontis [106], [107]. Although g index data are not available at the major data download sites, they can be generated using Harzing's free Publish or Perish software [108].

More generally, at least 37 variants of the h index have been proposed, and at least 35 studies have examined the correlations between two or more of those variants [109]. Most are closely related, with typical r values between 0.80 and 0.90. For a comprehensive overview of the h index and related metrics, see Egghe [98].

C. IMPACT FACTOR (IF) AND RELATED METRICS

The impact factor, one of the earliest and most widely used citation metrics, was first mentioned by Eugene Garfield in 1955. It was developed in the 1960s and made available through JCR in 1975 [4], [110]. Garfield's company, the Institute for Scientific Information (ISI), was acquired by Thomson Reuters in 1992, and the ISI databases were transferred to Clarivate Analytics, a spin-off company, in October 2016.

The data sites discussed in Section IV provide data for both IF and a number of variants. As shown in Table 1,

- *IF (impact factor)* is the average number of times the articles published in the journal over a two-year period (the two years prior to the report year) were cited during the report year.
- *Citations per document (2 years)*, presented at the SCImago web site, is identical to IF but calculated using data from Scopus rather than Web of Science.
- *IF without self-citations* is the same as IF, but with journal self-citations excluded from the numerator.
- *5IF (five-year impact factor)* is the average number of times the articles published in the journal over a five-year period (the five years prior to the report year) were cited during the report year.
- *CiteScore* is the average number of times the articles published in the journal over a three-year period (the three years prior to the report year) were cited during the report year.
- *IPP (impact per publication)*, previously called *RIP (raw impact per publication)*, is the average number of times the articles published in the journal over a three-year period (the three years prior to the report year) were cited during the report year. It is similar to IF, but based on three years' source documents rather than two.
- *CCI (Cabell's classification index)* is the average number of times the articles published in the journal (time period not specified) were cited during the report year and the previous two years. CCI is standardized—expressed as a z score—so that it represents the journal's relative importance within its subject category. For journals listed in multiple subject categories, CCI is calculated separately for each one.

As noted in Section II.G, IF and 5IF have been criticized for including citations to all types of items in the numerator (the citation count) but including just citable items in the denominator (the number of papers published in each journal). There is no such difficulty with either CiteScore or IPP.

D. SOURCE NORMALIZED IMPACT PER PAPER (SNIP)

SNIP is a size-independent metric developed by Henk Moed of the Centre for Science and Technology Studies (CWTS) at Leiden University [83]. SNIP is derived from IPP (Section III.C), but each value is normalized to account for the total number of citations in the journal's subject field. That is, a citation in a field where citations are less common (where lists of cited references are shorter) is assigned a higher weight than a citation in a field where citations are more common (where lists of cited references are longer). As discussed in Section II.H, SNIP incorporates citation potential, the average number of references per paper in each subject area [73], [83]. By accounting for citation potential, SNIP allows for the comparison of journals from different fields of study. For instance, *Modern Language Quarterly* and *Cellular Signaling* have the same SNIP value—the same relative standing within their disciplines—despite the fact that their IPP values are 0.22 and 4.20, respectively. This approach is consistent with a basic economic principle, that scarcity increases value. Although the number of references (citations) within each subject area is not fixed, it is constrained by the number of published papers and by the typical number of references per paper. Modern language scholars are competing for a smaller number of citation opportunities than biochemists, so a citation in literary history is valued more than a citation in biochemistry.

Although scholars have studied the statistical characteristics of SNIP ever since its introduction, the method of calculating SNIP has been modified just once, in October 2012 [111]–[114]. The revised version of SNIP corrects two anomalies. With the original SNIP metric, (a) an additional citation to a journal could result in a lower SNIP value if the citing publication had many references per article, and (b) in the case of a journal merger, the new journal could have an initial SNIP value lower than those of both its predecessors. Comparing the old and new formulations of SNIP for more than 22,000 journals, Waltman *et al.* [114] found that the two versions of the metric are closely related ($r = 0.93$).

E. EIGENFACTOR (EF), EFn, AND ARTICLE INFLUENCE SCORE (AI)

Two related metrics, EF and AI, were developed by Carl Bergstrom and Jevin West at the University of Washington [96], [115]. Like SNIP, these metrics are normalized to account for field-specific differences in impact.

Moreover, they are weighted to account for the impact of each citing journal. EF and AI were introduced in January 2007.

The Eigenfactor web site present three related metrics, which are also available through JCR.

- *EF (eigenfactor)* is a size-dependent metric based on the number of times the articles published in the journal over a five-year period (the five years prior to the report year) were cited during the report year. EF is scaled so that the values for every journal in the Web of Science database (Core Collection) add up to 100.
- *EFn (normalized eigenfactor)* is a simple rescaling of EF so that the average value is 1.00.
- *AI (article influence score)* is a size-independent metric based on EF. The mean AI value is 1.00.

All three indicators use a five-year cited-document window rather than the two-year window of IF, thereby increasing their robustness—their stability over time and across samples [116]. The five-year window may be especially appropriate for the social sciences and humanities, where citations accrue more slowly than in the natural sciences. Bergstrom [117], Jacsó [118], and West *et al.* [119] provide good overviews of EF and related metrics.

F. SCImago JOURNAL RANK (SJR)

SJR was developed by Félix de Moya-Anegón and Vicente Guerrero Bote at the Spanish National Research Council (CSIC) and the University of Extremadura [120]. It is based on the average number of times the articles published in each journal over a three-year period (the three years prior to the report year) were cited during the report year.

Like SNIP and AI, SJR is a size-independent metric normalized to account for differences in citation rates across disciplines. Like AI but unlike SNIP, SJR weights each citation based on the importance of the citing journal. In this context, *importance* refers to network centrality. "The SJR algorithm begins by assigning an identical amount of prestige to each journal. Next, this prestige is redistributed in an iterative process whereby journals transfer their attained prestige to each other through [the citation network]" [120, p. 381].

SJR allows self-citations to account for no more than one-third of the citations that accrue to each journal. This practice limits the influence of self-citation in an attempt to curtail the possibility of manipulative citation practices (e.g., editors asking authors to cite the journal in which their work will appear) [79].

SJR has been modified once [121]. The revised metric, first called *SJR2* but now known simply as *SJR*, accounts for both the impact of the citing journal and its distance from the cited journal within the citation network. (Citations count for more when the citing and cited journals are closely related.) Comparing the old and new versions of SJR, Guerrero-Bote and de Moya-Anegón [121] found that the new version more effectively accounts for disciplinary differences in impact. That is, the average SJR values for a range of disciplines are more nearly equal when the new SJR metric is used.

IV. DATA SOURCES AND SITES

A. DATA SOURCES

Any citation statistic will vary with the data used in its calculation. For instance, the three main data sources used in journal rankings—Web of Science, Scopus, and Google Scholar—each give different results when used to calculate IF, since each data source is unique in its journal coverage [50], [122]. Specifically,

- The WoS Core Collection, maintained by Clarivate Analytics, includes Science Citation Index as well as Social Sciences Citation Index, Arts & Humanities Citation Index, Conference Proceedings Citation Index, Book Citation Index, and Emerging Sources Citation Index. It provides more complete coverage of the natural and social sciences than the humanities. Although WoS includes data for more than 18,200 journals, it is nonetheless highly selective. Only 10–12% of the journals considered for inclusion each year are accepted into the database, and every WoS journal has met stringent standards for citation impact, timeliness of publication, and compliance with international editorial conventions [123]. WoS also includes more than 80,000 books and 9.8 million conference papers [124].
- Scopus, maintained by Elsevier, includes more than 22,700 journals along with selected book series and conference proceedings. The natural and social sciences are represented well, but Scopus is weaker in its coverage of the arts and humanities [125], [126].
- Google Scholar has the broadest coverage of the three databases. It provides data for approximately 87% of all the English-language scholarly documents available on the web: journal articles, preprints, conference papers, theses, research reports, and other items [127]. Google Scholar's coverage is most comprehensive in the sciences, where more of the scholarly literature is available online.

Meho and Rogers [128] suggest that the choice of a data source should depend on the degree of selectivity desired—on whether citations in lesser journals and conference proceedings ought to be counted, for instance. Based on the number of journals included in each database, we can conclude that GS provides more comprehensive citation coverage than Scopus, and that Scopus, in turn, provides more comprehensive coverage than WoS. This assertion has been supported by empirical studies in a wide range of subject areas including accounting, computer science, engineering, information science, and medicine [104], [129]–[135].

It is important to keep in mind that the methods used to construct the GS database are fundamentally different from those used for WoS and Scopus. While the other two databases cover particular journals in their entirety, Google Scholar's coverage is document- and publisher-based rather than journal-based. Specifically, GS gets its bibliographic records and citations from three sources: (a) freely available web documents that "look scholarly" to the GS web crawlers; (b) articles or documents supplied by Google

TABLE 3. Data sites for the standard citation metrics shown in Table 1.

Site	Data source	No. of journals included	Subject categories (broad & detailed)	Available data (single yrs.)	Size-dependent citation metrics	Size-independent citation metrics
Journal Citation Reports (JCR)	WoS	11,365[a]	234	1997+[b]	Total citns., EF	IF, 5IF, AI
Eigenfactor (EF)	WoS	11,200[a]	243	1997+	EF, EFn	AI
CWTS Journal Indicators	Scopus	22,956	27 & 306	1999+	None	IPP, SNIP
SCImago Journal & Country Rank	Scopus	29,713	27 & 313	1999+	Total citns. (3 yrs.), *h* index	Citns. per doc (2 yrs.), SJR
Scopus Journal Metrics (SJM)	Scopus	22,712	27 & 334	2011+	Total citns. (3 yrs.)	% Cited, CiteScore, SNIP, SJR
Cabell's International	WoS, Scopus[c]	11,272	7 & 17	2014+	None	IF, CCI
Google Scholar Metrics (GSM)	GS	N.A.[d]	8 & 260	2011+[e]	*h5* index, *h5* median	None

Journal Citation Reports and Cabell's International require subscriptions. The citation metrics available at the SJM site are provided to Elsevier by CWTS and SCImago.

[a] Although WoS covers more than 18,200 journals, not all of them are included in JCR and EF.

[b] Some metrics are available from 1997 to the present, while others (including EF and AI) are available only from 2007 to the present.

[c] Cabell's uses WoS data to calculate IF but Scopus data to calculate CCI.

[d] Not applicable; see accompanying text.

[e] 2011–2015 (all years combined); single years' data are not available.

Scholar's partner agencies: publishers, scholarly societies, database vendors, and academic institutions; and (c) citations extracted from the reference lists of previously indexed documents [136]–[138]. GS therefore provides full coverage of some journals and partial coverage of others. Moreover, GS uses automated methods that require almost no human intervention. This precludes the correction of errors by humans but also ensures that subjective opinion does not enter into the data compilation process. A journal with a dubious history or reputation is allowed to compete for citations on the same basis as any other journal. GS therefore permits the identification of high-impact articles within lower-impact journals.

B. DATA SITES

The seven web sites that provide access to citation-based journal ranking data (Table 3) are distinct from the underlying data sources. For instance, citation metrics based on Scopus data are available through several different web sites.

The first five sites shown in Table 3—JCR [139], the Eigenfactor site [140], CWTS Journal Indicators [141], SCImago Journal & Country Rank [142], and Scopus Journal Metrics [143]—provide broad coverage of the natural and social sciences, pure and applied, with more limited coverage of the humanities.

In contrast, Cabell's International [144] is limited to business (four subfields), education, educational technology and library science, psychology and psychiatry, mathematics and science (seven fields), computer science, health, and nursing. Along with the metrics shown in Table 3, Cabell's presents *acceptance rate* and *difficulty of acceptance*—the relative number of contributions from authors at top universities—for roughly half the journals in the database. Although Cabell's maintains minimum standards for inclusion, it is far from comprehensive in its coverage of good journals [145], [146]. For example, the library science rankings omit several high-impact journals such as *Library & Information Science Research*.

Google Scholar Metrics (GSM) [147] covers all subject areas. As discussed in Section IV.A, the strengths and limitations of the underlying data source make GSM fundamentally different from the other data sites.

As Table 3 reveals, the scope of each data site is not always the same as the scope of the underlying data source. For example, JCR provides data for fewer than two-thirds of the journals included in WoS. Cabell's makes use of data from both WoS and Scopus but does not present all the data available from either source. Likewise, the number of subject categories varies between CWTS, SCImago, and SJM despite the fact that all three draw on the same Scopus data.

The seven sites also differ in their data presentation and download options (Table 4). JCR, CWTS, SCImago, and GSM each allow users to download the complete data set (all journals) as well as data for the journals in each subject category. Google Scholar citation data can be viewed online or extracted through the free Publish or Perish software developed by Harzing [108]. The Scopus Journal Metrics interface is more restrictive, however; it does not permit users to download individual subject files. Finally, the Eigenfactor site and Cabell's International do not provide any straightforward method of extracting data for multiple journals. They may nonetheless be helpful for users who want to look up data on particular journals of interest.

V. CAVEATS AND CRITICISMS

A. FUNDAMENTAL PROBLEMS

A fundamental problem with citation metrics is that not all citations mean the same thing. A citation may honor the groundbreaking work of previous investigators, point out the shortcomings of an earlier study, or simply acknowledge

TABLE 4. **URLs and download options for the data sites shown in Table 3.**

Journal Citation Reports (JCR)
http://wokinfo.com/products_tools/analytical/jcr/
Requires subscription.
All subject categories combined; individual subject categories. 500-record limit per download.

Eigenfactor (EF)
http://www.eigenfactor.org/projects/journalRank/journalsearch.php
No systematic download capabilities.

CWTS Journal Indicators
http://www.journalindicators.com/
All subject categories combined; individual subject categories. Up to 1,000 records can be effectively downloaded by copying and pasting, which maintains the tabular format but limits the number of downloadable fields. The complete data file (all subjects) can be downloaded from http://www.journalindicators.com/methodology. To interpret the detailed subject category codes in the data file, see the All Science Journal Classification (ASJC) Codes in the documentation at http://ebrp.elsevier.com/pdf/Scopus_Custom_Data_Documentation_v4.pdf

SCImago Journal & Country Rank
http://www.scimagojr.com/
All journals combined; individual subject categories; individual regions/countries.

Scopus Journal Metrics (SJM)
https://www.journalmetrics.com/
All subject categories combined; results of individual title keyword searches. Individual subject categories cannot be presented or downloaded. To download the complete data file (all subjects), the user must supply a name and e-mail address.

Cabell's International
https://www.cabells.com/
Requires subscription.
No systematic download capabilities.

Google Scholar Metrics (GSM)
https://scholar.google.com/citations?view_op=top_venues
Use the *Categories* drop-down menu to see particular subject areas.
No systematic download capabilities.

the existence of a paper. In counting citations, we are counting behaviors that arise in response to a diverse range of situations and motives [3], [57], [148], [149]. One can make a case that critical or negative citations ought to be counted, however, since a paper that generates commentary within the scholarly community, for whatever reason, has had an impact on the field. As noted in Section II, the central construct for all citation metrics is not quality, but impact.

A closely related issue is that citations do not allow us to gauge the relative importance of the cited paper to the citing paper. A work that is mentioned in passing gets the same credit as one that is discussed at great length. To estimate the prevalence of important and less important citations, Kacmar and Whitfield [150, p. 396] examined the citations to 70 articles published in two Academy of Management journals. They noted, for each citation, whether the cited paper was the main focus of the citing article. "For example, a test of a theory or a model posited in the original article would be coded as the main focus of the citing article." Although the 70 articles were cited 1,528 times, only 122 of those citations (8%) met the "main focus" criterion. Among the 70 articles, the correlation between *number of citations* and *number of main-focus citations* was only moderate ($r = 0.55$). Likewise, Todd *et al.* [151], [152] found that 24% of the citations in 51 ecology journals and 18% of the citations in 33 marine biology journals did not directly support the assertions made by the citing authors. Their review of the literature reveals that similar percentages, ranging from 7–35%, have been reported for various health science fields.

Another major concern is that citations do not normally account for contributions to teaching and practice [3], [48], [55]. Most citation analyses are based on the assumption that "the principal (or sole) 'users' of scientific information are those who cite it in other academic journals" [153, p. 122]. Unlike citation-based rankings, survey-based rankings can be designed to account for the perspectives of practitioners as well as scholars [12].

No citation database covers all relevant journals, and the extent of journal coverage varies considerably by discipline [3], [47], [154]–[157]. Moreover, WoS and Scopus provide only partial coverage of citing works other than journal articles. The "journals-cite-journals" assumption is not defensible in fields such as computer science, where a significant proportion of all original research is published in conference proceedings rather than journals [158]. Likewise, books remain important in many disciplines [45], [159].

Users of journal rankings should keep in mind that the impact of a particular article cannot be inferred from the impact of the journal in which it was published. This is well known among scholars in the field of information science, yet it is often mentioned as a criticism of the metrics themselves [47], [48], [78], [160]. Seglen [65], [161] was perhaps the first author to show conclusively that journal impact and article impact are not necessarily related, and his findings have since been supported by further empirical research [162]–[166]. Although journal impact is a significant predictor of article impact [167]–[170], it is a mistake to draw conclusions about particular articles based on the characteristics of the journals in which they appeared. In the natural sciences, the average correlation between IF and the two-year article citation rate is only moderate—approximately 0.70. In the social sciences, it is lower—about 0.50. Moreover, the relationship between journal impact and article impact has weakened since 1990, perhaps due to the growing importance of full-text databases (e.g., ScienceDirect) and the associated decline in the extent to which journals are read or examined *as journals*—as monthly or quarterly issues [65], [161], [163], [171]. Researchers seeking to evaluate the impact of particular articles, rather than journals, are advised to use article-level metrics [33].

B. METHODOLOGICAL CONCERNS

Along with these fundamental criticisms, a number of methodological concerns have been discussed in the literature. Stern [172] asserts that journal ranking statistics are estimates based on multi-year distributions, and that reported differences in IF, or any similar metric, do not necessarily represent real differences in impact. From that perspective, significance tests are necessary whenever we wish to assess whether one value is higher than another. Stern's assertion is not valid, however, if we accept that each citation metric represents only the data used in its calculation—if we conclude not that Journal A has a greater impact than Journal B, but that Journal A had a greater impact in a particular year, based on the works cited in the set of journals included in the underlying data source [173].

Other problems may arise when a single paper or journal is presented in multiple versions. As Bornmann *et al.* [160] have pointed out, the providers of citation data are not always consistent in their handling of different-language versions of the same journal (i.e., *Angewandte Chemie*), and substantial inflation of citation counts can result when authors cite both versions of the same publication. Difficulties may also occur when Open Access drafts or preprints are cited separately from the final versions of the same papers.

Four additional methodological concerns have already been discussed in Section II:

- The cited-document windows of some citation metrics may be too short to accurately represent journal impact in fields where citations accrue slowly (Section II.D).
- Most citation metrics include journal self-citations. An unscrupulous editor may enhance the apparent impact of his or her journal by encouraging authors to cite it (Section II.F).
- Nearly all size-independent metrics are averages (means). The mean may misrepresent the impact of a typical article when the distribution of citations is skewed (Section II.G).
- Several size-independent metrics, including IF, count all citations in the numerator but only ''citable items'' in the denominator (Section II.G).

C. SYSTEMATIC BIASES

Studies of citation metrics have uncovered a number of biases, in which factors other than apparent journal quality are consistently correlated with either high or low citation impact. Journals that publish many review articles tend to be highly cited, as do those that report on broadly applicable methods such as statistical tests and laboratory techniques. In contrast, journals that publish only in narrow, specialized subfields often have lower citation impact than journals that are comparable in quality but broader in scope [3], [47], [55], [57], [174]–[176]. Within economics, in particular, several scholars have argued that citation metrics such as IF discount the importance of key journals within subfields that are not strongly linked to the disciplinary core. This can be seen for subfields that are distinctive in their subject emphases (e.g., economic history, history of economic thought) and for those that adopt theoretical perspectives outside the mainstream (e.g., Austrian, evolutionary, feminist, institutional, and Marxian economics) [47], [58], [177], [178]. By reinforcing the centrality of mainstream economics journals, citation metrics may further marginalize heterodox viewpoints [148]. In much the same way, indicators such as IF may understate the importance of journals devoted to topics of local rather than international interest [179].

Citation metrics have been linked to a range of covariates: journal circulation, initial advantage (e.g., early founding date or early association with a scholarly society), average article length, extent of English-language text, number of editorial board members, average number of authors per article, and the number of WoS subject categories in which the journal is listed [3], [45], [47], [179]–[182]. Balaban [183] has argued that because of these biases, scholars should give extra credit for high-impact papers that appear in low-impact journals. After all, such papers have often achieved prominence despite the factors working against them—low circulation/readership, limited coverage in bibliographic databases, and bias against less prestigious journals.

D. ERRORS IN SUBJECT CLASSIFICATION

Other criticisms deal not with the metrics themselves, but with the ways in which they are presented for viewing and downloading. In particular, no major provider of citation statistics has been entirely successful in defining and using coherent subject categories [184]–[186].[4] For instance,

- Journals from distinct fields of study are sometimes grouped into a single subject category. In 2010, the EF site used a single category for both physics and chemistry [187], and the CWTS and SCImago sites currently combine sociology with political science. Likewise, the WoS ''information science & library science'' category represents at least two distinct disciplines [188]–[191].
- Journals from the same subject area are sometimes split across two or more categories. This is currently the case for political science journals, which can be found in at least two SCImago categories: ''sociology and political science'' and ''political science and international relations.''
- Some subject categories correspond to entire disciplines while others represent narrow subspecialties. In 2010, the EF site maintained a separate category for plastic surgery despite the fact that most of its 64 subject categories were much broader—and despite the fact that no specific categories were used for more prominent surgical specialties such as thoracic surgery, orthopedic surgery, and vascular surgery [187].
- Many of the subject categories are too broad, too narrow, or simply too idiosyncratic to be useful for purposes

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[4] As Waltman & van Eck [84] have pointed out, source normalized metrics do not rely on predefined subject categories when accounting for disciplinary differences in impact, since their normalization procedure is based on the reference lists of particular articles. However, this approach does not eliminate the need to delineate subject areas when presenting journal lists to database users.

such as library collection development or the evaluation of academic departments. Categories such as ‘‘physics,’’ ‘‘finance,’’ and ‘‘pharmacy’’ are generally useful, while those such as ‘‘food animals’’ and ‘‘safety research’’ are of more limited utility.
- Particular journals are sometimes misclassified for no apparent reason. For example, CWTS and SCImago both count *Portal: Libraries and the Academy* as a development studies journal. *Developmental Psychology* and *European Union Politics* are both presented as top demography journals. The SCImago humanities category once included journals in a wide range of scientific fields, including pharmacology and engineering [192], and *Financial Research Letters* was formerly listed in the infectious diseases category [187]. Although the more egregious errors appear to have been corrected, misclassifications are still not difficult to find.

It is important to keep in mind that disciplines are not just subject areas, but research communities with distinctive traditions, assumptions, attitudes toward theory, standards of evidence, methodological priorities, and publication norms. If we uncritically accept the subject classifications put forth by the providers of citation data, we risk comparing journals that differ not only in subject coverage, but in other important ways.

E. FACTORS THAT LIMIT THE UTILITY OF CITATION DATA SITES

Download limitations and idiosyncrasies in presentation are real impediments to the use of citation metrics for large-scale projects. Until recently, both JCR and the Eigenfactor site listed journals by abbreviated title—the *American Journal of Respiratory Cell and Molecular Biology* appeared as ‘‘AM J RESP CELL MOL,’’ for instance—and none of the seven data sites are consistent in their use of ampersands in journal titles; their use of colons, dashes, or other punctuation before journal subtitles; or the inclusion of ‘‘The’’ as an initial title word. These difficulties hinder bibliometric research and library collection development work, which can require the merging and reconciling of dozens of data files. Likewise, some data sites make it difficult to find basic information that would be of obvious interest to scholars and practitioners. As shown in Table 1, at least two sites fail to provide complete information about the metrics they present.

Two of the seven sites provide no systematic download capabilities, and only four allow users to download the complete data set as well as data for the journals in particular subject categories (Table 4). More generally, few providers of citation data seem to have taken the needs of scholars and librarians into account. For instance, many librarians will want fields representing both current and former journal titles, publisher names that correspond to companies rather than imprints, and unique identifiers that allow the matching of records (rows) from multiple data sets. Title and ISSN are not suitable for this purpose, since they are presented differently, and sometimes incorrectly, within the various databases.

Although 19 citation metrics are publicly available, users may have only a few options once the relevant data and download limitations are taken into account. For example, a research evaluation committee may require a citation metric that satisfies four conditions: (a) size-independent, (b) not normalized to account for disciplinary differences in impact, (c) available for journals not covered by JCR, and (d) available as a set of data files, one for each subject area. These are straightforward and realistic criteria, but Tables 1, 3, and 4 reveal that only two metrics—IPP (through CWTS) and *citations per document* (through SCImago)—meet all four conditions.

Finally, the various data sites ought to present the citation distributions associated with particular journals and subject areas—measures of dispersion and skewness, along with graphs showing the actual citation distributions [179], [193]. This would allow more meaningful comparisons and would permit the use of inferential statistics, as recommended by Stern [172].

VI. LOOKING FORWARD

The citation metrics that have been introduced in recent years are less diverse than those developed in the past. For instance, most standard citation metrics count only the citations found in journals, conference papers, and a limited range of books. Citations found in other scholarly works—textbooks, reading lists, and dissertations, for instance—are not incorporated into journal rankings as often as they once were [34]–[42]. The widespread use of large-scale citation data from sources such as WoS, Scopus, and GS is probably good for the discipline of information science, since it allows us to better understand the systematic relationships that apply across subject areas. Unfortunately, there is an accompanying disadvantage; the unique characteristics of particular disciplines are not always recognized, understood, or incorporated into citation-based rankings. Recent studies have not accounted for the fact that citations may represent ‘‘apples’’ in one field but ‘‘oranges’’ in another [78], and the role of citations in the humanities has been largely ignored.

With the proliferation of citation metrics in recent years, Waltman and van Eck [100] have urged caution in the development of new ones. This guide suggests that all four of the recommendations put forth by Waltman [25, p. 383] are valid: ‘‘Do not introduce new citation impact indicators unless they have a clear added value relative to existing indicators .... Pay more attention to the theoretical foundations of citation impact indicators .... Pay more attention to the ways in which citation impact indicators are being used in practice .... Exploit new [and old] data sources to obtain more sophisticated measurements of citation impact.’’

We should also remember that citation metrics have always had an advantage over survey-based metrics due to the clarity of their central construct: scholarly impact [12]. When we introduce controls for multiple other factors, such as disciplinary differences in impact, the meaning of that central construct becomes less certain. Does it represent impact relative to other journals in the same field? In the same *sub*field? Impact relative to the journals that are nearest in the citation network? Impact adjusted for the total impact of the citing journal, or for the impact of the citing journal relative to others in its field? From a commonsense perspective, it seems unrealistic to pretend that each field of study is similar in its influence or importance—that *Political Analysis* should rank alongside the *Journal of the American Chemical Society*. Those two journals are nearly identical in their SJR values, but the construct represented by SJR is no longer simply *impact*.

As noted in Section I, journal rankings are useful to several audiences. Arguably, the largest group consists of authors seeking to identify the outlets most appropriate for their own research. This kind of use ought to be encouraged, since it facilitates the placement of each paper in the journal for which it is best suited. In turn, the "correct" placement of papers allows the scholarly community to better gauge the character of each contribution on the basis of the journal in which it has appeared. After all, journals provide value not just by selecting papers, improving them, and making them accessible, but by branding and marketing them in ways that helps scholars identify relevant research.[5] (In terms of both character and impact, a paper on Cuban emigration that appears in *Telos* is likely to be different from one that appears in the *Quarterly Journal of Economics*.) As search engines, online archives, and full-text databases gain primacy as access mechanisms, it is possible that journals will "remain relevant [only] if acceptance of research for publication within a journal allows readers to infer immediate, reliable information on the value of that research" [170, p. 1].

Finally, it is noteworthy that the link between journal impact and article impact has been weakening over time [65], [161], [163], [171]. This can be interpreted in at least two ways—either negatively (if authors fail to consider journal reputation and impact when submitting their work) or positively (if authors consider journal reputation and impact along with other characteristics such as scope, accessibility, intended audience, and style of presentation). The first scenario implies that journals are losing their utility as signalers of the kinds of papers they publish. The second scenario carries no such implication. Instead, it suggests that authors are appropriately considering a broad range of factors when deciding where to submit their work.

ACKNOWLEDGMENTS

I am grateful for the comments of Esther Isabelle Wilder and three anonymous referees.

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[5] As Davis [194, p. 198] has noted, journals are most important not as distribution mechanisms, but as agents that certify (review) scholarly work, curate contributions, and convene communities of interested and engaged scholars. "*Curating* suggests that what is published in a particular journal is likely to be worth reading."

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