The Operationalization of "Fields" as WoS Subject Categories (WCs) in Evaluative Bibliometrics: The Cases of "Library and Information Science" and "Science & Technology Studies"

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Normalization of citation scores using reference sets based on Web of Science subject categories (WCs) has become an established ("best") practice in evaluative bibliometrics. For example, the Times Higher Education World University Rankings are, among other things, based on this operationalization. However, WCs were developed decades ago for the purpose of information retrieval and evolved incrementally with the database; the classification is machine-based and partially manually corrected. Using the WC "information science & library science" and the WCs attributed to journals in the field of "science and technology studies," we show that WCs do not provide sufficient analytical clarity to carry bibliometric normalization in evaluation practices because of "indexer effects." Can the compliance with "best practices" be replaced with an ambition to develop "best possible practices"? New research questions can then be envisaged.

Introduction

The subject categories of the Web of Science (WoS) have increasingly evolved from a classification scheme for retrieval into a standard for normalizations in bibliometric evaluations. Because publication and citation practices can be expected to differ among fields of science, one cannot compare units across fields without proper classification of "like with like" (Martin & Irvine, 1983, p. 61): one should not compare apples with oranges or, in other words, books from the humanities with journal articles in fields with rapid research fronts such as biochemistry (Price, 1970). But because most units under evaluation are mixed in terms of their disciplinary composition, baselines are needed for the comparison.

The impact factor (IF) cannot be used for this evaluation because, like other bibliometric indicators, this measure varies itself systematically among fields of science. Garfield (1972) introduced the IF deliberately with a citation window of only the last two years of cited articles in order to focus on activities at the research front (Bensman, 2007; cf. Martyn & Gilchrist, 1968), but not all fields entertain research fronts to the same extent or by using similar communication channels (Leydesdorff, 2008).

Schubert and Braun (1986) introduced the normalization of citation rates as relative to expected citation rates. Using a subset of 400 physics journals, these authors defined the so-called relative citation rate (RCR) as the mean observed citation rate divided by the mean expected citation rate, where the latter is based on the average in a reference set. Relative citation rates can then be computed for subsets. Normalization against the average citation rate of similar publications (in terms of document types) in the same journal provides an obvious candidate for the delineation of a reference set, but normalization at the field level requires composed sets of journal literature. The unambiguous classification of journals using citation matrices, however, has remained an unsolved problem in bibliometrics (Leydesdorff, 2006; Rafols & Leydesdorff, 2009).

Boyack and Klavans (2011) noted that many journals are not sufficiently disciplinarily organized to be used as units of analysis for the normalization. Bradford's Law of Scattering (1934) and Garfield's (1971) Law of Concentration predict

that topics are scattered over journals: Subject sets are inherently fuzzy and cannot be semantically defined by words (Bensman, 2001). Schubert, Glänzel, and Braun (1989; cf. Braun et al., 1994) already noted that "the field/subfield classification of papers is a neuralgic point of all kind of scientometric evaluations" (p. 7). They used the classification system of Computer Horizons Inc. (CHI) that is still current for the *Science and Engineering Indicators* of the National Science Board of the USA (National Science Board, 2014). Moed, De Bruin, and Van Leeuwen (1995, p. 386) proposed using the "ISI journal categories" as reference sets. These journal categories were mainly computer-generated on the basis of title words from the very start of the *Science Citation Index* in the 1960s.

Using the Institute of Scientific Information (ISI) journal categories for the delineation of reference sets in terms of journals, Moed et al. (1995) developed the measure CPP/FCSm—citations per publication compared to the mean citation score of a field—as an addition to FCC/JCSm, that is, the equivalent but then normalized at the level of a journal. This CPP/FCSm was advocated by the Leiden Center for Science and Technology Studies (CWTS) as the "crown indicator." More recently, CPP/FCSm has been replaced by a "new crown indicator": MNCS, or the "mean normalized citation score" (Waltman et al., 2011, p. 37). In the Leiden Ranking 2014,[1] MNCS is no longer defined with reference to journals or sets of journals, but based on categories that are algorithmically generated from citation relations among papers (Ruiz-Castillo & Waltman, 2014; Waltman & van Eck, 2012).[2]

The ISI journal categories were renamed into the WoS subject categories (WC) with the introduction of the current version 5 of the WoS in 2009 (Leydesdorff, Carley, & Rafols, 2013). Unlike the Computer Horizons Inc.-National Science Foundation (CHI-NSF) classification—that is currently maintained by Patent Board™ under a contract with the NSF—more than a single WC can be attributed to each journal. In bibliometric evaluations, a journal is commonly attributed a percentage proportional to the categories under which it is subsumed. These multiple categories have also been considered as an indication of the interdisciplinarity of journals, and the overlaps among categories accordingly are assumed to exhibit the complexity ("interdisciplinarity") of the journal structures (Bordons, Morillo, & Gómez, 2004; Katz & Hicks, 1995; Morillo, Bordons, & Gómez, 2001). However, different categories may cover similar sets of journals; for example, in the biomedical domain (Rafols & Leydesdorff, 2009, p. 1830). In other cases, the categories

added by an indexer may generate relations among otherwise unrelated journals. This can be useful for purposes of information retrieval, but blurs the analytical distinctions.

In the meantime, the use of these journal categories has become accepted as "best practice" among bibliometric practitioners (e.g., Rehn et al., 2014). The Flemish ECOOM unit for evaluation in Leuven, however, uses a different classification system for journals (SOOI) specifically developed by this unit (Glänzel & Schubert, 2003). Other authors have refined the journal lists within specific WCs for a more precise evaluation of a given discipline (e.g., van Leeuwen & Calero-Medina, 2012). In the meantime, another journal classification system in terms of fields and subfields has been made available by Scopus.[3] However, we focus here on the WCs because these are so widely used for the normalization in bibliometric practices.[4]

For example, InCites—a customized, web-based research evaluation tool developed by Thomson Reuters—routinely provides normalizations of citation impact using these WCs for the delineation of the reference sets (e.g., Bornmann and Marx, 2014; see also Costas, van Leeuwen, & Bordons, 2010). Since 2003, the *Journal Citation Reports* (*JCR*) also provide the medians of impact factors for each journal category. Using the normalization in terms of WCs, for example, Leydesdorff et al. (2014) and Bornmann, Wagner, and Leydesdorff (in press) studied nations in terms of their contributions to the top-1% most highly cited publications.

Note that this delineation of reference sets in terms of journals may be pragmatic, but reference sets can also be defined in terms of (combinations of) keywords or thesauri (Bensman & Leydesdorff, 2009). For example, *Chemical Abstracts* contains high-quality classification terms at the level of each paper (Bornmann et al., 2009; Neuhaus & Daniel, 2009), and Medline/PubMed provides a system of medical subject headings (MeSH) at the paper level (Leydesdorff & Opthof, 2013; Rotolo & Leydesdorff, in press). The advantage of WoS (and Scopus), however, remains their "multidisciplinarity" in the sense that all disciplines are covered. When properly normalized, a comparison among different institutional units can thus be envisaged.

However, Pudovkin and Garfield (2002) warned that the ISI—currently Thomson Reuters—assigns journals to categories by "subjective, heuristic methods" (p. 1113n):

This method is "heuristic" in that the categories have been developed by manual methods started over 40 years ago. Once the categories were established, new journals were assigned one at a time. Each decision was based upon a visual examination of all relevant citation data. As categories grew, subdivisions were established. Among other tools used to make individual journal assignments, the Hayne-Coulson algorithm is used. The

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algorithm has never been published. It treats any designated group of journals as one macrojournal and produces a combined printout of cited and citing journal data.[5]

According to these authors, the categories are sufficient, but they added that "in many areas of research these classifications are crude and do not permit the user to quickly learn which journals are most closely related" (p. 1113). Boyack et al. (2005) estimated that the attributions could be correct in approximately 50% of cases across the file (Boyack, personal communication, September 14, 2008). Rafols and Leydesdorff (2009) concluded that the ISI subject categories can be used for statistical purposes, but not for a detailed evaluation. In the case of interdisciplinary fields, problems of imprecise or potentially erroneous classifications can be expected (Haustein, 2012, p. 101). Let's explore this question about the quality of the WCs empirically.

Empirical Examples: LIS and STS

As cases to illustrate our argument about the problems with using WCs for normalization, we focus on the two fields with which we are most familiar so that we are able to validate the results: library and information science (LIS) and science and technology studies (STS). Of course, these cases are specific, but, in our opinion, all fields of science are more or less specific.

In *JCR* 2012, 85 journals were assigned to the category "information science & library science," which is abbreviated in the classification system as "NU." These 85 journals are attributed 131 WCs or on average 1.54 WC/journal. Eighteen of the other attributions are to "computer science, information systems" (ET), 11 to the "management" category (PC), and the others occur three times or less frequently. *JASIST*, for example, is additionally assigned to the category ET ("computer science, information systems"), whereas *Scientometrics* is classified as "computer science, interdisciplinary." The *Journal of Informetrics* is uniquely attributed to "information science & library science."

One can construct an aggregated journal–journal citation matrix among these 85 journals using *JCR* 2012. Seventy-six of these 85 journals (89%) contain references to one of the other journals in the set.[6] All journals, however, are cited in this domain except *Informacios Tarsadalom*, a Hungarian journal founded in 2001. This journal was cited only once in the entire *JCR* 2012.

Using a network analysis and visualization program such as Pajek or VOSviewer, one can map the journal–journal citation matrix after normalization for relative weights of the citation vectors using the cosine, and thus obtain, for example, Figure 1. Figure 1 shows how the fields and disciplinary delineations are actively reproduced by current (that is, 2012) citation behavior, whereas the cited patterns (in Figure 2) inform us about the archival structures.

Both maps clearly exhibit a major divide between the LIS journals, on the one side, and the information-systems journals (red-colored nodes), on the other. In the latter group *MIS Quarterly* is the leading journal with a journal impact factor (IF) 2012 of 4.659, whereas *Journal of Informetrics* has the highest, IF(2012) = 4.153, among the LIS journals. However, these two journals did not cite each other in 2012.

One would expect the second category "ET," which stands for "computer science, information science," to be indicative of this division, but, as noted, this classification is also attributed to *JASIST*, which is a central journal of LIS. Of the 84 journals in Figure 2, 27 are classified as belonging to the second partition (red-colored nodes), but only eight of these 27 are attributed to the WC "computer science, information systems" (among them *MIS Quarterly*). However, *Information Systems Journal, Information Systems Research*, and *MIS Quarterly Executive* are not provided with this attribution.

The LIS group shows a fine structure of 25 journals in the information sciences (green-colored nodes) and 22 in library science (white-colored nodes). Using another method, Waltman, Yan, and van Eck (2011, p. 306) distinguished three subsets of journals in this group: information science (14 journals), library science (27 journals), and scientometrics (nine journals). In Figure 2, six journals form a separate partition of journals in Spanish and Portuguese (pink-colored in Figure 2). These latter journals are indistinguishable from the larger set when analyzing their referencing patterns, but they are cited differently. Thus, a community-finding algorithm (Blondel, Guillaume, Lambiotte, & Lefebvre, 2008) classifies them with the other LIS journals when focusing on citation behavior. In evaluative bibliometrics, however, one is interested in normalizing in terms of "being cited," and not in "citing" behavior (Nicolaisen, 2007; Wouters, 1998). Thus, the difference in citation when writing in languages other than English is relevant for the normalization.

In summary, the attribution of WCs to journals can be confusing. The classification does not work properly for the normalization even in more detailed cases. For example, when defining "informetrics" (or "iMetrics"; see Milojević & Leydesdorff, 2013) in terms of *Journal of Informetrics* (*JoI*), *Scientometrics*, and a subset of *JASIST*, current evaluation practices would count *JoI* for 100% in the reference set because it is designated as "NU" exclusively as a single class, whereas the other two journals are each normalized for 50% with reference to this set and for 50% with reference to two other sets. Perhaps this makes no significant differences among distributions of large units (such as

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[5]Pudovkin & Fuseler (1995) further specified the Hayne-Coulson algorithm as follows: "The number of citations each journal receives from different specialty core journals is obtained annually by a computer routine (Hayne-Coulson) that is used to create the JCR database" (p. 228).

[6]The nonciting journals in 2012 are: *Annual Review of Information Science and Technology, Econtent, Informacios Tarsadalom, Information Research: An International Electronic Journal, Information Technology and Libraries, Journal of Organizational and End User Computing, Libraries & the Cultural Record, Online*, and *Scientist*. There can be different reasons for this, for example, when a journal no longer exists but remains part of the cited archive (e.g., *ARIST*). Other journals (e.g., the *Scientist*) do not contain references.
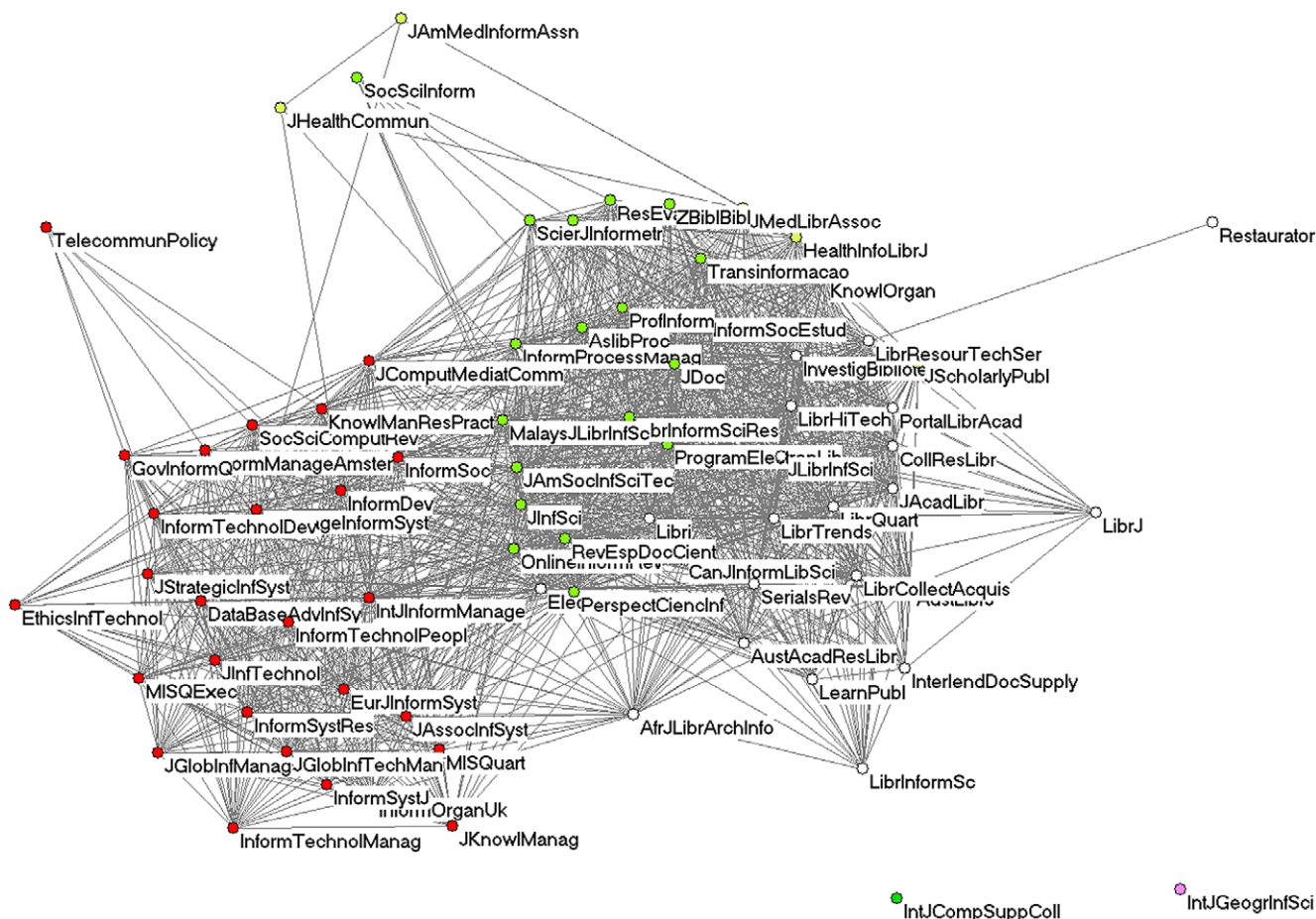
FIG. 1. Map of 76 (of the 85) journals in the category "information science & library science" of *JCR* 2012 (*citing*); *cosine* > 0.05; *Q* = 0.376 (Blondel et al., 2008). Kamada and Kawai (1989) is used for the visualization. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

countries; cf. Glänzel, 2010), but this process seems insufficiently precise for a professional evaluation at the institutional or individual levels.

Science and Technology Studies

Many scholars in evaluative bibliometrics consider STS or more broadly "science, technology, and innovation studies" as their professional identity although methodologically scientometrics has become part also of the information sciences. The CWTS in Leiden, for example, hosted a major conference in this field under the title "19th International Conference on Science and Technology Indicators" in September 2014.

How can this professional identity be appreciated in the evaluation? Unlike LIS, STS cannot be identified by a single WC. Using citation analysis at the level of journals, STS can be defined differently from various angles (Leydesdorff & Van den Besselaar, 1997), and although institutionalized to some extent, it can also be considered as transient (Leydesdorff, 2007; Van den Besselaar, 2001) or meta-stable because one translates continuously between the interdisci-

plinary specialty of STS and the mother disciplines (such as the sociology of science and technology, history and philosophy of science, business and management, etc.). However, the quantitative side of STS (including scientometrics) has become increasingly important in recent decades. Using journals and citations in a set of routines for the classification of 109,164 potentially relevant articles published between 1956 and 2012, Milojević et al. (2014, p. 696; cf. Martin et al., 2012) were able to show that quantitatively oriented STS studies have in the meantime become more important in terms of numbers of publications than qualitative STS (Figure 3).

Although it may be difficult to delineate STS unambiguously in terms of journals, the WC contains a category "social science, interdisciplinary" (WU). One would expect many of the relevant journals to be in this category. Table 1, however, tells us a different story.

Because there is only marginal overlap in the attribution of WCs to these journals most relevant for STS, it is impossible to evaluate an STS unit using WCs for the normalization. Rafols, Leydesdorff, O'Hare, Nightingale, and Stirling (2012) made the point that journal rankings on lists tend to
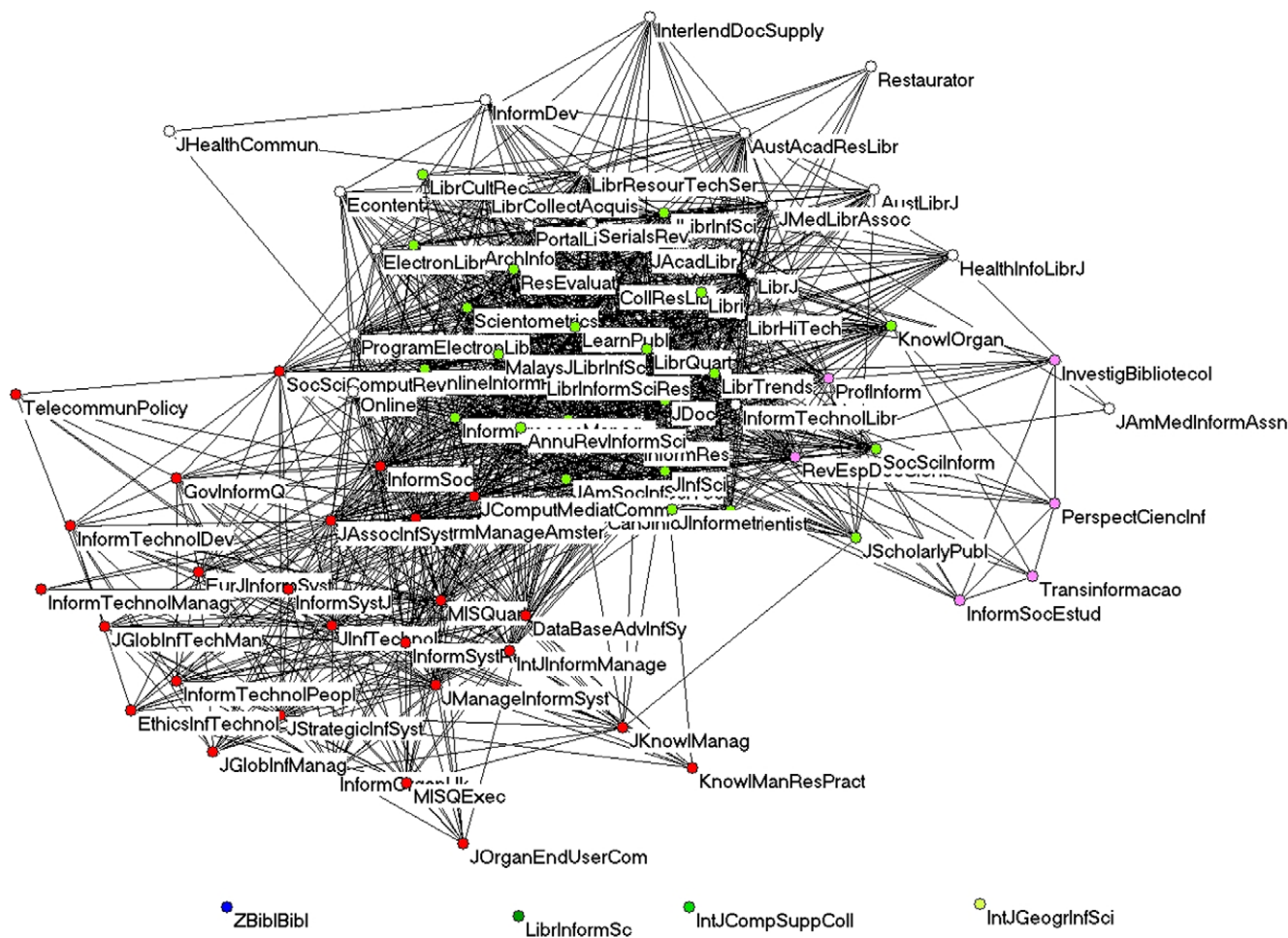
FIG. 2. Map of 84 (of the 85) journals in the category "information science & library science" of *JCR* 2012 (*cited*); *cosine* > 0.05; $Q = 0.318$ (Blondel et al., 2008). Kamada and Kawai (1989) was used for the visualization. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]
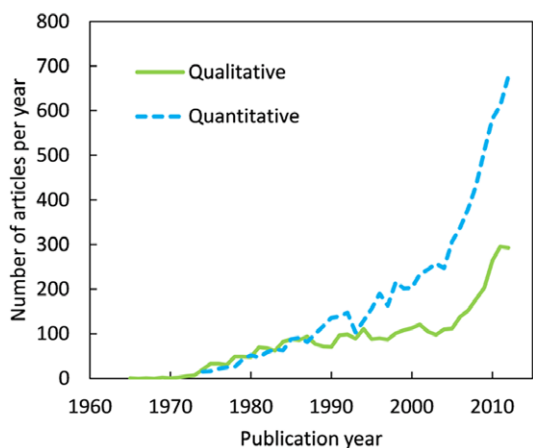

FIG. 3. Number of journal articles in the area of STS published between 1965 and 2012. (Source: Milojević et al., 2014, p. 696.) [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

push interdisciplinary units to the margins, using the case of "innovation studies" in the evaluation environment of "business & management." This marginalization is further reinforced when there is no common denominator as in the

TABLE 1. WoS categories for eight STS journals.

	WoS category	Abbreviation
Scientometrics	Information science & library science	NU
	Computer sci., interdisciplinary	EV
Social Studies of Science	History and philosophy of science	WM
Research Policy	Management	PC
	Planning & development	UQ
Science, Technology and Human Values	Social issues	WM
Science & Public Policy	Management	PC
	Planning & development	UQ
	Public administration	VM
Minerva	Education & educationals research	HA
	History & philosophy of science	MQ
	Social science, interdisciplinary	WU
Science Communication	Communication	EU
R&D Management	Business	DI
	Management	PC

list of Table 1. Evaluees may be increasingly sensitive to evaluation systems that thus provide institutional incentives to return to disciplinary perspectives (Dahler-Larsen, 2012).

Conclusion

The WCs have been used increasingly for the selection of reference sets of journals in bibliometric evaluations. One can seriously doubt whether the journals themselves are sufficiently disciplinarily oriented to be used for the normalization (Boyack & Klavans, 2011). The confusion, however, is potentially aggravated by collapsing sets of journals on grounds that remain otherwise unspecified. We showed the possible problems by providing two examples of the journal sets with which we are most familiar: one discipline that is attributed a WC ("information science & library science") and one specialty (STS) that is not attributed a WC. In both cases, normalizations using these categories might seriously harm the quality of the evaluation. There is no reason to see these fields as exceptions.

What are the alternatives? One would expect the classification systems of Scopus and the alternative offered by Glänzel and Schubert (2003) to do a better job for the simple reason that these classifications of journals were developed in the early 2000s with bibliometric analysis in mind, whereas the WCs have developed incrementally since the early times of the *Science Citation Index* in the 1960s and 1970s for the purpose of facilitating information retrieval. The WCs have been adapted piecemeal ever since; for example, the number of WCs has grown in *JCR* from 204 in 1994 to 226 currently,[7] and a number of journals have been reclassified.

The use of (sets of) journals is not the only way to generate reference sets for the evaluation of institutional units or individuals. Alternatively, one can explore the use of professionally developed index terms for the delineation, such as the MeSH in Medline/PubMed or *Chemical Abstracts* (e.g., Bornmann et al., 2009; Rotolo & Leydesdorff, in press). Another option is to consider the citing papers, that is, the audience of a given paper, as a reference set. This idea is applied when counting citations fractionally (Leydesdorff & Bornmann, 2011; Zitt & Small, 2008). One problem, however, may be the "double citation window" thus generated, because one would have to wait until the citing papers are sufficiently cited.

A more radical approach involves clustering the citations at the level of the papers in the database, as done by CWTS (Waltman & van Eck, 2012), and as used in the Leiden rankings. The latter, for example, are based on normalization against 828 "fields," that is, algorithmically generated clusters of citation relations. Because the fields are algorithmic artifacts, they cannot easily be named (as different from numbered), and therefore cannot be validated. Furthermore,

a paper has to be cited or contain references in order to be classified, because the approach is based on direct citation relations; the journal names are used as a second index key to attribute the noncited papers to the most resembling clusters. Note that Rafols and Leydesdorff (2009) found that algorithmically generated classifications of journals have characteristics very different from content-based classifications (as predicted by Garfield, 1955). The Leiden system is not only difficult to validate, it also cannot be accessed or replicated from outside its context of use (cf. Ruiz-Castillo & Waltman, 2014).

Perhaps one could also normalize without the specification of reference sets; for example, on the basis of "universal" properties of the distributions (e.g., Radicchi, Fortunato, & Castellano, 2008). In summary, opening the metaphor of "best practices" to the challenge of "best possible practices" may provide us with new research perspectives (e.g., Butler, 2010; Colliander, in press). Kostoff and Martinez's (2005) rhetorical question as to whether citation normalization is realistic seems to drive a research program in evaluative bibliometrics. However, caution may be advised in suggesting valid normalizations in professional practices until the problems of how to define reference sets are further solved.

Acknowledgment

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[7]Twenty-three more categories are specifically included in the Arts & Humanities Citation Index (A&HCI; Leydesdorff, Hammarfelt, & Salah, 2011).

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