# Normalization, CWTS indicators, and the Leiden Rankings: Differences in citation behavior at the level of fields

Loet Leydesdorff<sup>1</sup> & Tobias Opthof<sup>2, 3</sup>

Abstract: Van Raan *et al.* (2010; <u>arXiv:1003.2113</u>) have proposed a new indicator (*MNCS*) for field normalization. Since field normalization is also used in the Leiden Rankings of universities, we elaborate our critique of journal normalization in Opthof & Leydesdorff (2010; <u>arXiv:1002.2769</u>) in this rejoinder concerning field normalization. Fractional citation counting thoroughly solves the issue of normalization for differences in citation behavior among fields. This indicator can also be used to obtain a normalized impact factor.

## Introduction

In their rejoinder entitled "Rivals for the crown: Reply to Opthof & Leydesdorff," Van Raan *et al.* (2010) accepted our critique for the case of journal normalization (*CPP/JCSm*). However, a completely new indicator is proposed for field normalization (previously *CPP/FCSm*), called the "mean normalized citation score" (*MNCS*). In our opinion, this change does not sufficiently resolve the problems. Since the new indicator is proposed as the new "crown indicator" (Waltman *et al.*, in preparation), it seems urgent to warn against and elaborate on the remaining problems. In addition to damaging

<sup>&</sup>lt;sup>1</sup> Amsterdam School of Communications Research (ASCoR), University of Amsterdam, Kloveniersburgwal 48, 1012 CX Amsterdam, The Netherlands.

<sup>&</sup>lt;sup>2</sup> Department of Medical Physiology, University Medical Center Utrecht, Utrecht, The Netherlands.

<sup>&</sup>lt;sup>3</sup> Experimental Cardiology Group, Heart Failure Research Center, Academic Medical Center AMC, Meibergdreef 9, 1105 AZ Amsterdam, The Netherlands.

evaluation processes at the level of individuals (PIs) and institutions, the "crown indicator" is also used by CWTS for the "Leiden Rankings," and flaws in it can therefore misguide policies at national levels.

Our previous critique focused on journal normalization because the journal indicator is analytically the simpler case. Journals provide clearly delimited units of analysis, while fields are compounded constructs. Formally, the CWTS indicators for journal and field normalizations could be considered as equivalent:

$$\frac{CPP}{JCSm} = \frac{((c_{1i}+c_{2i})+c_{3j}+c_{4k})}{(2J_i+J_j+J_k)}$$
(1)

$$\frac{CPP}{FCSm} = \frac{((c_{1i}+c_{2i})+c_{3j}+c_{4k})}{(2F_i+F_j+F_k)}$$
(2)

In the first example (Eq. 1), the first two articles are published in the same journal (*i*) and normalized against the average of the citations of the reference set (in terms of, for example, document types and publication years) in this same journal, whereas the other two articles (*j* and *k*) are evaluated with reference to their respective reference sets. In Equation 2, the same is done for fields, but instead of the 8000+ journals of the ISI set, in this case the 221 ISI Subject Categories are used for the normalization. Note that various values for *F* will be equal in the case of different journals when the latter are subsumed under the same field or category. In other words, journal normalization is more finely grained than field normalization (Rafols & Leydesdorff, 2009), yet nevertheless the latter is considered by the CWTS as the "crown indicator." We have objected that the mean citation score can be properly normalized as follows respecting the arithmetic order of operations:

mean citation score = 
$$\left(\frac{c_{1i}}{J_i} + \frac{c_{2i}}{J_i} + \frac{c_3}{J_i} + \frac{c_4}{J_k}\right)/4$$
 (3)

In addition to the mean, the distribution (between the brackets in Eq. 3) also provides other statistics such as a standard deviation and the median.

Van Raan *et al.* (2010) counter-argue that the order of operations is just a convention which can be circumvented by placing brackets as in Equations 1 and 2. Our argument therefore is deemed "irrelevant." Of course, we understand that one can place brackets and thus force a change in the order of operations. However, changing the order of operations by using brackets also changes the meaning, traceability, and transparency of the indicators and evaluation outcomes. In other words: 3/2 plus 2/3 is mathematically different from 5/5 and has another meaning as an indicator. By changing the order of operations, one loses the possibility to use statistics to determine whether observed differences are also significant.

Furthermore, the effects on the rankings at the level of individual researchers and research groups can be significant. We demonstrated this in the case of the research evaluation of the Academic Medical Center of the University of Amsterdam: it could be shown that one scholar who was rated by the Leiden evaluations as precisely on the world average was not significantly different in her<sup>4</sup> citation score from another scholar who belonged to the top group. The Leiden indicators fail to test for significance, and CWTS consequently never provides error bars in the graphs.

As elsewhere (e.g., CWTS, 2008, at p. 7), Van Raan et al. (2010) provide references to Schubert & Glänzel (1983) or Glänzel (1992) to legitimate a difference of 0.2 as significant when unity is considered as "the world average." However, this value of 0.2 is not statistics, but a rule of thumb. In the interval between zero and one, 0.2 has a meaning different from above the world average because this interval is not limited to one to two. However, Schubert & Glänzel (1983) based their reasoning on normal distributions (Glänzel, 2010). The reasoning can be used to estimate error in large sets (Glänzel, *personal communication*, 16 November 2009), but the estimator is insufficiently precise for evaluations of smaller sets. The alternative of bootstrapping mentioned by Van Raan et al. (2010) as another possible strategy makes the issues unnecessarily complex and has not yet been applied by CWTS. These references, in our opinion, disguise the fact that a statistics is missing from the CWTS evaluations, while our measures allow for the application of standard tests such as Kruskall-Wallis, as was demonstrated in our previous contributions (Opthof & Leydesdorff, 2010; Leydesdorff & Opthof, in preparation).

Let us add that we were pleasantly surprised by the flexibility of CWTS to adapt its indicator to our criticism (Waltman *et al.*, 2010). We note that some other centers (e.g., ECOOM in Leuven and ISSRU in Budapest) continue to use the quotient between the

<sup>&</sup>lt;sup>4</sup> In order to respect anonymity, we use "her" as gender neutral.

Mean Observed Citation Rates (MOCR) and the Mean Expected Citation Rates (MECR) as a main indicator (Glänzel *et al.*, 2009, at p. 182) using as an argument that the mean of the expectations is not a statistical function, but an expectation based on a set and therefore a real value (Glänzel, 2010; Glänzel, *personal communication*, March 18, 2010). It seems to us that this inference is only valid for large sets. In our opinion, institutional and *a fortiori* individual evaluations are to be tested using non-parametric statistics.

### **Field normalization**

We focused on journal normalization because in the case of field normalization, one has two problems: the scientometric one of how to delineate fields and the statistical one of how to normalize. Journals are delineated units of analysis. Van Raan *et al.* (2010) have accepted our critique in the case of journal normalization, but it seems to us that a new "crown indicator" is being hastily proposed for field normalization, with the mean normalized citation score (*MNCS*) taken as an alternative to *CPP/FCSm* (Equation 2). Like *CPP/FCSm*, *MNCS* is based on the ISI Subject Categories for weighing citation scores, as follows:

$$NMCS = \left(\frac{c_{1i}}{F_i} + \frac{c_{2i}}{F_i} + \frac{c_3}{F_j} + \frac{c_4}{F_k}\right) / 4 \tag{4}$$

The weights are derived from the average citation scores within each subject category. Equation 4 is analogous to our Equation 3, but now for fields instead of journals in the respective denominators. Although we now agree about the statistical normalization, this new "crown indicator" will inherit the scientometric problem of the previous one in treating subject categories as a standard for normalizing differences in citation behavior among fields of science.

- The ISI Subject Categories were not designed for the scientometric evaluation, but for the purpose of information retrieval. Despite a strong denial by Van Raan *et al*. (2010) who formulate: "we are not aware of any convincing evidence of large-scale inaccuracies in the classification scheme of WoS," the subject categories lack an analytical base (Boyack *et al.*, 2005; Pudovkin & Garfield, 2002, at p. 1113n.; Rafols & Leydesdorff, 2009) and are not literary-warranted (Bensman & Leydesdorff, 2009; Chan, 2005). As Opthof & Leydesdorff (2010) have explained in greater detail, alternative and far more precise classification schemes are available. Why not evaluate an academic hospital on the basis of the Medical Subject Headings (MeSH) of the bibliographic database MedLine, which are publicly available and compiled on a paper-by-paper basis (Bornmann *et al.*, 2009. at p. 98)?
- 2. If papers are published in journals which are attributed to several subject categories, CWTS chooses to weigh each category equally. This procedure generates artifacts in the rankings, since some journals are highly specialized (e.g., in cardiology) but nevertheless subsumed under a number of categories (for the purpose of information retrieval). The distinctions among categories are not based on multivariate analysis of the citation matrix among journals or weighted in terms of numbers of citations (Leydesdorff, 2006; Pudovkin & Garfield, 2002).

6

For example, the *Journal of Vascular Research* is attributed to the subject categories of "peripheral vascular disease" and "physiology," and the journal *Circulation* to "cardiac and cardiovascular systems," "hematology," and "peripheral vascular diseases"; whereas the *American Journal of Cardiology* is attributed only to "cardiac and cardiovascular systems." Scholars in these fields, however, publish and cite across such categorical divides.

3. The purpose of normalization at the field level is to control for differences in citation densities among fields. These differences are caused by differences in citation behavior among various fields of science. Mathematics, for example, is known to have a much lower citation density than the biomedical sciences. However, the easiest way to capture this difference in citation behavior is by fractional counting in the citing articles at the article level. The level of aggregation for the benchmarking can then still be decided, for example, in terms of ISI Subject Categories.

For example, if an author in mathematics cites six references, each reference can be counted as 1/6 of overall citation, whereas a citation in a paper in biomedicine with 40 cited references can be counted as 1/40. This normalization thoroughly takes field differences into account and the results allow for statistical testing. Most importantly, this normalization is independent from a classification system and thus there is no indexer effect.

The Leiden group argues in favour of the *MNCS* with reference to Lundberg (2007). Indeed, Lundberg (2007) previously signaled the statistical problem in the "crown indicator" (*CPP/FCSm*) used in the Leiden rankings and recommended *MNCS* as an alternative. Other institutes (e.g., the Karolinska Institute in Stockholm) have changed their procedures accordingly (Van Veller *et al.*, 2009). Why did CWTS not follow suit, but instead continued to evaluate research units and individual PIs with a measure that was known to be flawed? Instead of reproaching us for having missed this reference, CWTS should have taken immediate action, because these evaluations are used for allocation decisions at the group level and for promotion decisions at the individual level. When these practices are flawed, they can be also very harmful. Wrongly based allocation decisions not only affect individuals and groups, but can in the longer run also damage the scientific enterprise.

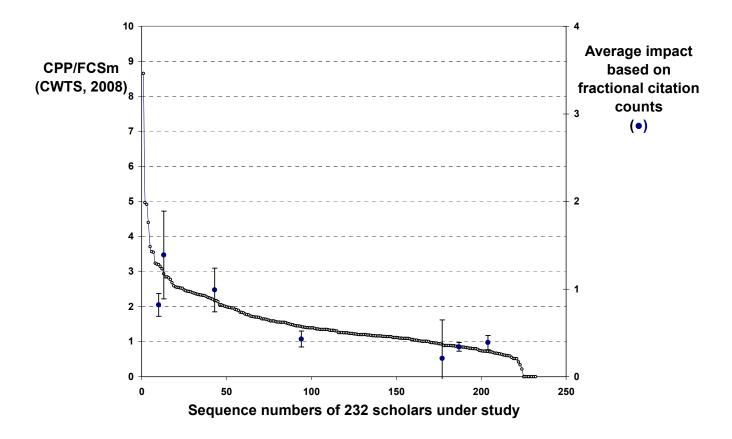
#### Fractional citation counting as field normalization

Moed (2010) has proposed returning to fractional counting of citations in terms of the citing papers when recently constructing the so-called *SNIP* indicator for the *Scopus* database. (*SNIP* stands for "situated normalized impact per paper.") The idea of normalizing by fractionating the citation impact proportionately was first developed by Narin (1976) and Pinski & Narin (1976), but elaborated by these authors in the different direction of so-called influence weights. Moed (2010), however, made the same mistake as previously when developing the Leiden indicators (Moed *et al.*, 1995), namely, to first add up and then divide in both the numerator and denominator of the *SNIP*-indicator. We

8

we acknowledge that the original idea is fruitful because one can normalize on the basis of the citing articles directly for citation behavior, instead of using averages among rather arbitrarily delimited sets, such as fields of science operationalized as ISI Subject Categories or otherwise (e.g., Glänzel & Schubert, 2003; cf. Rafols & Leydesdorff, 2009).

Let us now turn our critique into a constructive proposal by showing the difference between the journal normalization contained in our previous contribution to this debate and the field normalization proposed here using the same seven PIs in our sample of the 232 scientists evaluated at the AMC.



**Figure 1**: Ranking of 232 AMC scientists in terms of their *CPP/FCSm* (that is, field-normalized) according to the CWTS (2008); • average citation impact using fractional citation counting for seven of these scientists.

Figure 1 can be compared with Figure 1 in Opthof & Leydesdorff (2010), but the present ranking is based on the Leiden field normalization (*CPP/FCSm*) instead of the journal normalization (*CPP/JCSm*). (As noted, we did not obtain values for the new indicator *MNCS*, but instead use the *CPP/FCSm* provided by CWTS (2008) for the comparison.) One can observe by visual inspection of the two graphs that the differences in the normalized citation scores based on fractional counting are larger in this case than the correction in the previous case of journal normalization despite differences in the scales.<sup>5</sup> For us, this result does not come as a surprise because of the problem of the disturbing field delineations. In our opinion, the field-normalized "crown indicators" are less reliable than the journal-normalized indicator of CWTS.

	Bibliometric data			Journal normalized		Field normalized		
Rank	$\Sigma p_i$	$\Sigma c_i$	Avg(c/p)	Mean citation	CPP/JCSm	$\Sigma  c_{ m f}$	$Avg(c_{\rm f})$	CPP/FCSm
				score (previous	(CWTS,	(this	(this study)	(CWTS,
				study)	2008)	study)		2008)
6	23	891	38.74 (± 13.67)	2.03 (± 0.55)	2.18	31.95	1.39 (± 0.50)	2.94
14	37	962	$26.00 (\pm 4.09)$	1.74 (± 0.19)	1.86	30.32	0.82 (± 0.13)	3.20
26	22	567	25.77 (± 5.78)	$1.54 (\pm 0.23)$	1.56	21.74	0.99 (± 0.25)	2.17
117	32	197	6.16 (± 1.30)	$1.50 (\pm 0.29)$	1.00	6.83	0.21 (± 0.44)	0.92
118	37	402	$10.86 (\pm 2.21)$	$0.93 (\pm 0.13)$	1.00	16.08	0.43 (± 0.09)	1.43
206	65	647	9.96 (± 1.57)	0.91 (± 0.11)	0.58	21.90	$0.34 (\pm 0.05)$	0.87
223	32	354	11.06 (± 1.74)	0.78 (± 0.12)	0.43	12.40	$0.39 (\pm 0.08)$	0.72
	Spearman $\rho > 0.99$ ; $p < 0.01$				Spearman $\rho = 0.75$ ; <i>n.s.</i>			

<sup>&</sup>lt;sup>5</sup> Different from Figure 1 in Opthof & Leydesdorff (2010), the scales are now unequal because the average impact is based on fractional counting and *CPP/FCSm* on whole-number counting. A world average would require normalization against a fractionally counted impact factor for each journal. One would thus be able to combine field and journal normalization and develop what could perhaps be considered as "crown indicator."

Table 1 quantifies these effects. The journal normalizations in the middle of this table correspond to the figures provided in Table 4 of Opthof & Leydesdorff (2010). Whereas the journal normalizations correlate highly in terms of their rank ordering (Spearman's  $\rho > 0.99$ ; p < 0.01) despite considerable differences at the level of individual scores, the field normalizations no longer correlate even when using p < 0.05. One can expect values for the *MNCS* to be highly correlated with those for *CPP/FCSm* (Van Raan, 2010, at slides 31-34; Van Raan *et al.*, 2010, at p. 5; Waltman *et al.*, 2010), and therefore not with the weighted citation impact based on fractional counting.

Whereas we found, for example, no significant differences between the first and fourth authors in the case of journal normalization using a *post-hoc* test with Bonferroni correction, the differences between the first author and all other authors are significant when thus controlling for differences in citation behavior. The six other authors cannot be considered as different from one another in terms of their impact at the level of the field of citing authors.

In other words, while the previous evaluation highlighted a top group of four authors with no significant differences in their journal impacts, this evaluation distinguishes one top author with significantly more influence at the field level from a group of authors who are less influential. This result accords with notions of science as global elite structures (Merton, 1968 and 1973; Whitley, 1984). Journals can be expected to organize more specific hierarchies (e.g., Bollen *et al.*, 2005; Doreian & Farraro, 1985; Zsindely *et al.*, 1982).

Note that by using fractional citation counts one abandons the notion of a world average as a standard for a field of science. Given the overlaps among fields, this notion is, in our opinion, sociologically unwarranted. By using fractional citation counts, however, one can benchmark against any reference set including the ones subsumed under the ISI Subject Categories. The advantage is that one can then use standard statistics to determine whether the performance above or below this "world average" is also significant.

## **Conclusion and discussion**

In the previous paper, we provided the corrected normalization for journals as intended by the *CPP/JCSm*, and in this paper we have extended our analysis with an explanation of how to normalize at the level of fields of science in terms of differences in citation behavior using fractional citation counts. In our opinion, this normalization accords with the intention behind the "crown indicator" of CWTS, but the latter assumes the ISI Subject Categories as a manifestation of this difference in behavior.

Our measure can be generalized as normalization for any differences in citation behavior among citing authors. Note that authors can also differ in terms of their publication behavior, and that these differences can be systematic among fields of science. However, differences in publication behavior cannot be captured by a citation indicator. Fractional citation counting is simple and elegant. The resulting distributions can be analyzed statistically; error bars consequently can be indicated in the graphical results. The importation of indexer-based and potentially biased schemes of classification is no longer necessary. In another context (Leydesdorff & Opthof, 2010), we show that this measure can also be used to normalize the impact of journals by considering the citable issues in the denominator of the ISI-Impact Factor as a document set (in the years t - 1 and t - 2) which can be counted fractionally in terms of citations in the year t (in the numerator).

Using this normalization, for example, an influential journal in mathematics (in our case, *Annals of Mathematics*) has a higher impact weight than a journal in biomedicine (in this case, *Molecular Cell*) despite a five-fold difference in the ISI impact factors in favor of the latter. Thus, the measure is very general. As noted, we consider the Bonferroni correction *ex post* as an appropriate test for significance among different sets.<sup>6</sup> This test is available in statistical packages such as SPSS.

#### **References**:

- Bensman, S. J., & Leydesdorff, L. (2009). Definition and Identification of Journals as Bibliographic and Subject Entities: Librarianship vs. ISI Journal Citation Reports (JCR) Methods and their Effect on Citation Measures. *Journal of the American Society for Information Science and Technology*, 60(6), 1097-1117.
- Bollen, J., Rodriquez, M. A., & Van de Sompel, H. (2006). Journal status. *Scientometrics*, 69(3), 669-687.
- Bornmann, L., & Daniel, H. D. (2009). Universality of citation distributions—A validation of Radicchi et al.'s relative indicator  $c_f = c/c_0$  at the micro level using

<sup>&</sup>lt;sup>6</sup> Additionally, a robust test of the equality of the means is provided by the Welch statistics (Glänzel, *personal communication*, March 18, 2010). However, the means among these seven authors were significantly equal. In our opinion, one can also use Kruskall-Wallis for this purpose.

data from chemistry. *Journal of the American Society for Information Science and Technology*, 60(8), 1664-1670.

- Boyack, K. W., Klavans, R., & Börner, K. (2005). Mapping the Backbone of Science. *Scientometrics*, 64(3), 351-374.
- Chan, L. M. (2005). Library of Congress subject headings: Principles and applications. 4<sup>th</sup> ed. Library and information science text series. Westport, Conn.: Libraries Unlimited.
- CWTS (2008). AMC-specifieke CWTS-analyse 1997-2006. Leiden: CWTS [access via AMC intranet; unpublished, confidential].

Doreian, P., & Fararo, T. J. (1985). Structural Equivalence in a Journal Network. *Journal* of the American Society for Information Science, 36, 28-37.

- Glänzel, W. (1992). Publication Dynamics and Citation Impact: A Multi-Dimensional Approach to Scientometric Research Evaluation. In P. Weingart, R. Sehringer & M. Winterhagen (Eds.), *Representations of Science and Technology. Proceedings* of the International Conference on Science and Technology Indicators, Bielefeld, 10-12 June 1990 (pp. 209-224). Leiden: DSWO / Leiden University Press.
- Glänzel, W. (2010). On reliability and robustness of scientometrics indicators based on stochastic models. An evidence-based opinion paper. *Journal of Informetrics,* In print.
- Glänzel, W., & Schubert, A. (2003). A new classification scheme of science fields and subfields designed for scientometric evaluation purposes. *Scientometrics*, 56(3), 357-367.
- Leydesdorff, L. (2006). Can Scientific Journals be Classified in Terms of Aggregated Journal-Journal Citation Relations using the Journal Citation Reports? *Journal of the American Society for Information Science & Technology*, 57(5), 601-613.
- Leydesdorff, L., & Opthof, T. (2010). *Scopus*' Source Normalized Impact per Paper (*SNIP*) versus the Journal Impact Factor based on fractional counting of citations. *in preparation*.
- Lundberg, J. (2007). Lifting the crown—citation z-score. *Journal of informetrics*, 1(2), 145-154.
- Merton, R. K. (1968). The Matthew Effect in Science. Science, 159, 56-63.
- Merton, R. K. (1973). *The Sociology of Science: Theoretical and empirical investigations*. Chicago/London: University of Chicago Press.
- Moed, H. F. (2010). Measuring contextual citation impact of scientific journals. *Journal* of *Informetrics*, in print.
- Opthof, T., & Leydesdorff, L. (2010). Caveats for the journal and field normalizations in the CWTS ("Leiden") evaluations of research performance. *Journal of Informetrics,* in print.
- Pudovkin, A. I., & Garfield, E. (2002). Algorithmic procedure for finding semantically related journals. *Journal of the American Society for Information Science and Technology*, 53(13), 1113-1119.
- Rafols, I., & Leydesdorff, L. (2009). Content-based and Algorithmic Classifications of Journals: Perspectives on the Dynamics of Scientific Communication and Indexer Effects *Journal of the American Society for Information Science and Technology*, 60(9), 1823-1835.

- Schubert, A., & Glänzel, W. (1983). Statistical reliability of comparisons based on the citation impact of scientific publications. *Scientometrics*, 5(1), 59-73.
- Van Raan, A. F. J. (2010). Quantitative Studies Studies of Science: Outlook. Paper presented at the 3<sup>rd</sup> Intl. Conference of the European Network for Indicators Designers ENID, Paris, 5 March 2010.
- Van Raan, A. F. J., Van Leeuwen, T. N., Visser, M. S., Van Eck, N. J., & Waltman, L. (2010). Rivals for the crown: Reply to Opthof and Leydesdorff. *Journal of Informetrics*, 4(3), forthcoming.
- Van Veller, M. G. P., Gerritsma, W., Van der Togt, P. L., Leon, C. D., & Van Zeist, C. M. (2009). Bibliometric analyses on repository contents for the evaluation of research at Wageningen UR. In *Qualitative and quantitative methods in libraries : Theory* and Applications. Proceedings of the International Conference on QQML2009, 26-29 May 2009, Chania, Crete, Greece. Singapore: World Scientific, pp. 19-26.
- Waltman, L., Van Eck, N. J., Van Leeuwen, T. N., Visser, M. S., & Van Raan, A. F. J. (2010). Towards a New Crown Indicator: Some Theoretical Considerations. *In preparation*.
- Whitley, R. D. (1984). *The Intellectual and Social Organization of the Sciences*. Oxford: Oxford University Press.
- Zsindely, S., Schubert, A., & Braun, T. (1982). Editorial Gatekeeping Patterns in International Science Journals—A New Science Indicator. *Scientometrics*, 4(1), 57-68.