



Field-normalized citation impact indicators and the choice of an appropriate counting method[☆]



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ARTICLE INFO

Article history:

Received 14 May 2015

Received in revised form 30 July 2015

Accepted 3 August 2015

Available online 18 September 2015

Keywords:

Citation analysis
Counting method
Field normalization
Fractional counting
Full counting

ABSTRACT

Bibliometric studies often rely on field-normalized citation impact indicators in order to make comparisons between scientific fields. We discuss the connection between field normalization and the choice of a counting method for handling publications with multiple co-authors. Our focus is on the choice between full counting and fractional counting. Based on an extensive theoretical and empirical analysis, we argue that properly field-normalized results cannot be obtained when full counting is used. Fractional counting does provide results that are properly field normalized. We therefore recommend the use of fractional counting in bibliometric studies that require field normalization, especially in studies at the level of countries and research organizations. We also compare different variants of fractional counting. In general, it seems best to use either the author-level or the address-level variant of fractional counting.

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1. Introduction

In discussions on bibliometric indicators, two topics that receive a considerable amount of attention are field normalization and counting methods (for a review of the literature on these topics, see [Waltman, 2015](#)). Field normalization is about the problem of correcting for differences in citation practices between scientific fields. The challenge is to develop citation-based indicators that allow for valid between-field comparisons. Counting methods are about the way in which co-authored publications are handled. For instance, if a publication is co-authored by two countries, should the publication be counted as a full publication for each country or should it be counted as half a publication for each country?

The topics of field normalization and counting methods are usually discussed separately from each other. However, we argue that there is a close connection between the two topics. Our argument is that proper field normalization is possible only if a suitable counting method is used. In particular, we claim that properly field-normalized results cannot be obtained when one uses the popular full counting method, in which co-authored publications are fully assigned to each co-author. The fractional counting method, which assigns co-authored publications fractionally to each co-author, does provide properly field-normalized results. The problem of full counting basically is that co-authored publications are counted multiple times, once for each co-author, which creates a bias in favor of fields in which there is a lot of co-authorship and in which co-authorship correlates with additional citations. This is the essence of the argument that we present in this paper. Our

[☆] The peer review process of this paper was handled by Vincent Larivière, Associate Editor of *Journal of Informetrics*.

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Table 1
The authors of our example publication and the corresponding addresses.

Author	Address
Author 1 (first author)	Address 1
Author 2	Address 1; Address 2
Author 3	Address 3
Author 4 (corresponding author)	Address 3
Author 5	Address 4; Address 5

argument builds on an earlier paper (Waltman et al., 2012), but in the present paper we elaborate the argument in more detail and we also present an extensive empirical analysis.

The rest of this paper is organized as follows. In Section 2, we present the counting methods that we study in the paper and we provide an overview of earlier research on counting methods. We discuss the connection between counting methods and field normalization in Section 3. We also introduce the concept of the full counting bonus in this section. This concept plays a key role in our ideas on counting methods. An empirical analysis of the full counting bonus is reported in Section 4. Empirical comparisons between different counting methods are presented in Section 5. In Section 6, we discuss some commonly used arguments in favor of full counting, and we provide a response to each of these arguments. Finally, we draw conclusions in Section 7.

2. Counting methods

In this section, we first provide an overview of the different counting methods that we consider in this paper. We then present a simple example in which the different counting methods are illustrated. This is followed by a discussion of the choice between a number of fractional counting variants. Finally, we review earlier work on counting methods.

2.1. Overview of counting methods

Our main focus in this paper is on the comparison between full counting and fractional counting. In the case of full counting, a publication is fully assigned to each co-author. For instance, a publication co-authored by four countries counts as a full publication for each of the four countries. In the fractional counting case, a publication is fractionally assigned to each co-author. The weight with which a publication is assigned to a co-author indicates the share of the publication allocated to that co-author. The sum of the weights of all co-authors of a publication equals one. An example of fractional counting is the situation in which a publication co-authored by four countries is assigned to each country with a weight of $1/4 = 0.25$.

Fractional counting can be implemented in a number of different ways. In this paper, we distinguish between the following variants of fractional counting:

- *Author-level fractional counting.* Each author of a publication has equal weight.
- *Address-level fractional counting.* Each address listed in the address list of a publication has equal weight.
- *Organization-level fractional counting.* Each organization listed in the address list of a publication has equal weight.
- *Country-level fractional counting.* Each country listed in the address list of a publication has equal weight.

It is important to understand that the level at which fractional counting is performed does not need to be the same as the level at which the analysis takes place. For instance, the analysis may take place at the level of organizations or countries, but fractional counting may be performed at the level of authors or addresses. An example that illustrates this important point is provided in Section 2.2.

In addition to full and fractional counting, we also consider first author counting and corresponding author counting in some of the analyses presented in this paper. First author counting assigns a publication with a weight of one to the first author and with a weight of zero to each of the other authors. The underlying idea is that the first author of a publication often represents the most important contributor.¹ Corresponding author counting is similar to first author counting, but it assigns a publication with a weight of one to the corresponding author rather than to the first author. The other authors again have a weight of zero.

2.2. Example

To illustrate the different counting methods, we provide a simple example. We consider a publication that has five authors. The address list of the publication contains five addresses. Table 1 indicates which addresses belong to which authors. Table 2 shows the organization and the country mentioned in each of the addresses. Other address details, such as the department

¹ This idea is not applicable in fields in which the authors of a publication tend to be listed in alphabetical order. We refer to Frandsen and Nicolaisen (2010) and Waltman (2012) for detailed analyses of the phenomenon of alphabetical authorship.

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