Journal of Informetrics 6 (2012) 27–33

Contents lists available at SciVerse ScienceDirect

Journal of Informetrics

journal homepage: www.elsevier.com/locate/joi

Short communication

Quantifying the degree of research collaboration: A comparative study of collaborative measures

Chien Hsiang Liao[a,*], Hsiuju Rebecca Yen[b,1]

[a] Department of Information Management, National Central University, No. 300, Jhongda Rd., Jhongli City, Taoyuan 32001, Taiwan
[b] Institute of Service Science, National Tsing Hua University, No. 101, Sec. 2, Kuang-Fu Rd., Hsinchu 30013, Taiwan

ARTICLE INFO

Article history:
Received 24 July 2011
Received in revised form
15 September 2011
Accepted 15 September 2011

Keywords:
Research collaboration
Collaborative measures
Comparative study
Research productivity
Journal impact factor
Citation

ABSTRACT

This article reports a comparative study of five measures that quantify the degree of research collaboration, including the collaborative index, the degree of collaboration, the collaborative coefficient, the revised collaborative coefficient, and degree centrality. The empirical results showed that these measures all capture the notion of research collaboration, which is consistent with prior studies. Moreover, the results showed that degree centrality, the revised collaborative coefficient, and the degree of collaboration had the highest coefficient estimates on research productivity, the average JIF, and the average number of citations, respectively. Overall, this article suggests that the degree of collaboration and the revised collaborative coefficient are superior measures that can be applied to bibliometric studies for future researchers.

1. Introduction

For the past decades, the notion of research collaboration has been widely discussed in bibliometric studies. A way to think about collaboration is in terms of the extent to which resources fit research needs (Lee & Bozeman, 2005). Hence, research collaboration could be defined as researchers working together to achieve the common goal of producing new scientific knowledge (Katz & Martin, 1997). In general, research collaboration helps scholars to share their workloads (Hauptman, 2005; Presser, 1980), past experience (Hauptman, 2005), specific expertise or particular skills (Bammer, 2008; Soderbaum, 2001; Stillman, Wipfli, Lando, Leischow, & Samet, 2005), equipment or resources (Bammer, 2008; Stillman et al., 2005), and fresh ideas (Hauptman, 2005). Specifically for the research outcome, the influence of research collaboration has also been proven to be positively associated with research productivity (Eaton, Ward, Kumar, & Reingen, 1999; Hudson, 1996; Ponomariov & Boardman, 2010) and citation counts (Goldfinch, Dale, & DeRouen, 2003; Katz & Hicks, 1997; Sooryamoorthy, 2009). Because of the importance of research collaboration, several studies have attempted to quantify the concept.

Rousseau (2011) has made a summary of collaborative measures based on mathematical computation. He compared three well known measures of degree of collaboration, including the collaborative index (CI), the degree of collaboration (DC), and the collaborative coefficient (CC). As shown in his study, each of three measures has its shortcoming(s) in mathematical computation. For example, CC fails to yield 1 for maximal collaboration. Egghe (1991, p. 186) presented a revised collaborative coefficient (RCC), which he denotes as CC*, to overcome the shortcoming of the CC. In addition to four measures mentioned by Rousseau (2011) and Egghe (1991), the degree centrality has also been treated as the degree of research collaboration by

* Corresponding author. Tel.: +886 2 847 2429.
E-mail addresses: 944403010@cc.ncu.edu.tw (C.H. Liao), hjyen@mx.nthu.edu.tw (H.R. Yen).
[1] Tel.: +886 3 516 2146.

1751-1577/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.joi.2011.09.003

prior studies (Freeman, 1979). Hence, this study regards degree centrality as one of collaborative measure as well. However, beyond mathematics, other interesting questions remained for readers. First, as these measures were created or adapted by different studies, it is unclear whether these measures capture the same notion (i.e. the degree of research collaboration) or not. Therefore, the first research objective (RO1) of this article is to examine the correlation between these measures. In addition, future researchers may want to know how to choose an appropriate measure to examine the notion of research collaboration in their bibliometric studies. Hence, the second research objective (RO2) is to determine which measure was the best indicator in predicting the dependent variables that most researchers examine and that concern them, including research productivity (Lee & Bozeman, 2005), the impact factor (Bouyssou & Marchant, 2011) and citation counts (López-Illescas, de Moya-Anegón, & Moed, 2008; Sooryamoorthy, 2009). Because many prior studies treat the collaborative measure as an important factor, these questions should be discussed further. The purpose of this article was to address these questions based on the discussion by Rousseau (2011).

The remaining content of this article is organized as described below. Relevant research on several measures of quantifying the degree of research collaboration, including CI, DC, CC, RCC and degree centrality, is summarized. Then, an empirical study to examine the correlation between these measures and to explore which measure is best predictor of research outcomes (i.e. research productivity, impact factor, and citation counts) is presented. The research subjects were 55 Information Systems (IS) scholars and 63 Library and Information Science (LIS) scholars selected from the Social Science Citation Index (SSCI) database of the Information Sciences Institute (ISI). Finally, the implications of the results are discussed.

2. Measures of research collaboration

According to the discussion of collaborative measures by Rousseau (2011) and Egghe (1991), the equations of four measures are as follows.

f_j = the number of papers having j authors in the collection;
q = the maximal number of authors in a single paper;
N = the total number of papers; and
n = the total number of authors in the collection.

$$\textit{Collaborative index } (CI) = \frac{\sum_{j=1}^{q} j f_j}{N} \tag{1}$$

$$\textit{Degree of collaboration } (DC) = 1 - \frac{f_1}{N} \tag{2}$$

$$\textit{Collaborative coefficient } (CC) = 1 - \frac{\sum_{j=1}^{q} (1/j) f_j}{N} \tag{3}$$

$$\textit{Revised collaborative coefficient } (RCC) = \frac{n}{n-1}\left\{1 - \frac{\sum_{j=1}^{q} (1/j) f_j}{N}\right\} \tag{4}$$

The CI is used to measure the average number of authors per paper (Lawani, 1980). Although it is easily computable, it is not easily interpretable as a degree because it has no upper limit. Moreover, it gives a non-zero weight to single-authored papers that involve no collaboration. The DC is a measure of the proportion of multiple-authored papers (Subramanyam, 1983). It is easy to calculate, easily interpretable as a degree (for it lies between zero). However, the DC does not differentiate among levels of multiple authorships. The CC was designed to remove the shortcomings of the CI and DC (Ajiferuke, Burrell, & Tague, 1988); it vanishes for a collection of single-authored papers and distinguishes between papers of different numbers of authors. The CC lies between 0 and 1, with 0 corresponding to single-authored papers. However, the CC fails to yield 1 for maximal collaboration, except when the number of authors is infinite. The RCC not only keeps the benefits of the CC, but it also yields 1 when the collaboration is maximal (Egghe, 1991). More detailed, Egghe (1991) formulated eight natural principles that good collaborative measures should satisfy. The RCC satisfies most of natural principles.

In addition to the four measures mentioned by Rousseau (2011), *degree centrality* has been treated as a key factor in the degree of research collaboration (e.g. Freeman, 1979; Lu & Feng, 2009), and is defined as the number of connections that an author (a node) has with other authors. In the collaboration network, being a central author means that the scientist has collaborated with many colleagues (Otte & Rousseau, 2002); that is, an author's degree equals the number of nodes linked with it (Lu & Feng, 2009). In mathematical terms, the degree centrality, $d(i)$, of node i is defined as follows:

$$d(i) = \sum_j m_{ij}, \tag{5}$$

where $m_{ij} = 1$ if there is a link between the i and j nodes and $m_{ij} = 0$ if there is no such link. In a co-author graph, the degree centrality of a node is just the number of authors in the graph with whom he or she has co-authored at least one article. The