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
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.

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

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

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

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

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:

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

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

Table 1
Alphabetical list of scholars selected from premier IS journals (1999–2004).

Scholar	MISQ	ISR	JMIS	I&M	Scholar	MISQ	ISR	JMIS	I&M
Agarwal, R	5	2	0	0	Lederer, AL	0	0	1	3
Barki, H	1	2	1	0	Lee, AS	3	1	0	1
Benbasat, I	6	4	3	0	Lee, H	0	0	0	4
Bhargava, HK	0	1	3	0	Lee, S	0	0	0	4
Bhattacherjee	2	1	2	0	Love, PED	0	0	1	3
Chau, PYK	0	0	2	4	Lyytinen, K	2	1	1	0
Clemons, EK	0	0	6	0	Marakas, GM	1	2	0	1
De Vreede, GJ	0	0	4	0	Markus, ML	3	1	1	0
Dehning, B	1	0	1	2	Mukhopadhyay, T	0	2	2	0
Dennis, AR	2	2	2	0	Nunamaker, JF	0	0	6	0
Devaraj, S	0	1	3	0	Palvia, PC	0	0	0	4
Gallupe, RB	0	2	1	1	Purao, S	0	1	2	1
Gefen, D	1	1	2	0	Rai, A	1	1	1	3
Goodhue, DL	1	0	0	3	Reich, BH	2	1	1	0
Grover, V	1	1	3	3	Sabherwal, R	0	2	1	1
Gupta, A	2	2	2	1	Sambamurthy, V	4	3	1	0
Hitt, LM	0	2	2	0	Sethi, V	0	1	0	3
Huff, SL	2	1	0	1	Straub, DW	4	2	0	1
Irani, Z	0	0	1	4	Tam, KY	0	2	4	1
Jarvenpaa, SL	1	2	1	0	Tan, BCY	1	1	0	2
Jiang, JJ	1	0	2	10	Thatcher, ME	0	1	3	0
Kauffman, RJ	1	2	8	0	Thong, JYL	0	1	3	0
Keil, M	3	0	2	1	Torkzadeh, G	0	1	1	2
Klein, G	1	0	2	10	Wei, KK	2	1	0	2
Kohli, R	1	1	2	1	Whinston, AB	1	5	1	0
Kraemer, KL	0	2	2	0	Wixom, BH	2	0	1	1
Kumar, A	0	3	2	0	Zmud, RW	6	1	1	0
Kumar, RL	0	0	1	3					

degree centrality in an N-node network can be standardized by dividing by $N-1$ (Freeman, 1979; Otte & Rousseau, 2002) as follows:

$$d(i) = \frac{\sum_j m_{ij}}{N-1} \tag{6}$$

3. Methodology

3.1. Data collection

Following the approach of prior studies (e.g. Cronin, Shaw, & La Barre, 2004; Liu, Bollen, Nelson, & Van de Sompel, 2005; Oh, Choi, & Kim, 2005), this article also used the co-authorship of an article to symbolize research collaboration. However, using only one article to represent a scholar's research collaboration network is too arbitrary and could lead to bias. Thus, for this article, scholars were chosen who had published at least four articles in premier journals. In total, 118 scholars were selected from two sub-disciplines in the category of Information Science & Library Science using the SSCI database, one comprising 55 prolific scholars (see Table 1) who had published four or more articles in premier journals of Information Systems from 1999 to 2004, including *MIS Quarterly* (MISQ), *Information Systems Research* (ISR), *Journal of Management Information Systems* (JMIS), and *Information & Management* (I&M). The other sub-discipline comprised 63 prolific scholars (see Table 2) who had published six or more articles in premier journals of Library and Information Science from 1995 to 2004, including *Journal of the American Society for Information Science and Technology* (JASIST), *Scientometrics* (SCIM), *Journal of Information Science* (JIS), and *Information Processing & Management* (IP&M). Specifically, all the selected IS publications (*MISQ, ISR, JMIS*, and *I&M*) have been regarded as top-ranked or prior journals according to the Association for Information Systems (Clark & Warren, 2006), as well as the selected LIS publications, i.e. *JASIST, SCIM, JIS, IP&M* (Schloegl & Stock, 2004; White & McCain, 1998). The publication type was limited to research articles; other document types, such as editorial materials, proceeding papers, and review papers, were not included.

3.2. Measurement

The measures, including the CI, DC, CC, and RCC, were calculated following Eqs. (1)–(4), respectively. Moreover, the degree centrality was determined with the social network analysis software, UCINET (Borgatti, Everett, & Freeman, 1999), and it was implemented as follows. For example, 63 LIS scholars were selected from the SSCI database. The relationships between the 63 key scholars and their 317 peripheral co-authors were examined based on their collaborative relationships in journal articles. The relationships among the 380 scholars form a social network. Next, the relation

Table 2
Alphabetical list of scholars selected from premier LIS journals (1995–2004).

Scholar	JASIST	SCIM	JIS	IP&M	Scholar	JASIST	SCIM	JIS	IP&M
Aoe, J	0	0	0	9	Kumar, S	0	7	0	2
Bar-Ilan, J	2	5	1	0	Leta, J	0	6	0	0
Bhattacharya, S	0	7	0	0	Lewison, G	0	7	1	0
Braun, T	0	10	1	0	Leydesdorff, L	3	9	0	0
Burrell, QL	2	4	0	1	McMurdo, G	0	0	14	0
Cawkell, T	0	0	6	0	Meyer, M	0	9	0	0
Chen, CM	3	1	0	2	Moed, HF	0	7	1	0
Chen, HC	4	0	1	1	Morita, K	0	0	0	6
Choi, KS	0	0	0	8	Muir, A	0	0	6	0
Cole, C	2	0	0	9	Nagpaul, PS	0	7	0	0
Cronin, B	6	2	2	1	Nicholas, D	0	0	8	1
Dore, JC	1	6	0	0	Ojasoo, T	1	5	0	0
Egghe, L	5	14	2	7	Oppenheim, C	0	2	34	0
Eto, H	0	6	0	0	Padhi, P	0	6	0	0
Foo, S	1	1	6	2	Persson, O	0	9	0	0
Ford, N	7	0	4	0	Rousseau, R	5	16	2	5
Foster, A	6	0	0	0	Savoy, J	1	0	0	6
Fuketa, M	0	0	0	6	Schubert, A	0	10	0	0
Garfield, E	5	1	0	0	Spink, A	9	0	1	12
Garg, KC	0	13	0	1	Thelwall, M	6	6	8	4
Glanzel, W	0	19	1	0	Tsay, MY	1	5	0	0
Gupta, BM	0	21	0	1	van Raan, AFJ	0	6	0	0
Harries, G	1	1	4	0	Vinkler, P	1	8	1	0
Hartley, J	0	0	9	0	White, HD	4	2	0	2
Huber, JC	3	2	0	1	Wilkinson, D	2	1	3	1
Huntington, P	0	0	8	1	Williams, P	0	0	5	1
Ingwersen, P	2	6	0	1	Wilson, CS	3	5	0	0
Jarvelin, K	3	0	0	9	Wilson, TD	5	0	1	0
Jorgensen, C	4	0	0	2	Wolfram, D	4	1	1	3
Karisiddappa, CR	0	8	0	0	Zhang, J	2	0	3	3
Kim, MJ	0	2	3	1	Zobel, J	4	0	0	2
Kostoff, RN	1	4	2	1					

square (380 × 380) was computed as the input data in UCINET. Each cell of the relationship square represents the number of collaborations between two given scholars. Finally, the centralities of the 63 key scholars were calculated via a software function. Similarly, the article calculated the centralities of 55 IS scholars following the same procedure.

Research productivity was treated as the number of articles that a scholar published during a particular period, such as 1999–2004 or 1995–2004. The journal impact factor (JIF) was accessed from the Journal Citation Reports. Each journal has different impact factors in different years, so this article compiled the JIF values for all of a scholar's articles. For instance, Table 1 shows that Sambamurthy published four articles in *MISQ*, three articles in *ISR*, and one article in *JMIS* during 1999–2004; his aggregated value for the JIF was calculated as 1.171(MISQ, 1999) + 2 × 2.872 (MISQ, 2002) + 2.811 (MISQ, 2003) + .667 (ISR, 1999) + 2 × 1.093 (ISR, 2000) + 1.043 (JMIS, 2002), which equals 13.622. Therefore, the average JIF per article was 1.703.

Citation data were collected from the SSCI database. Because citations provide a dynamic index, the index may be underestimated during early periods when articles were published; therefore, this article did not include data on articles published in recent years but, instead, included articles published prior to 2004. In addition, the number of citations an article may receive after it is published greatly depends on its citation window in years. For instance, the citation period of the article published in 2000 is four years longer than that of the article published in 2004, which enjoys a longer period of citation counts. That is, if the majority of articles a scholar published were in early period, he or she will enjoy a longer period of citation counts. Moreover, Van Raan (2006) also restricted the citation period to a three-year window (i.e. the same citation period) instead of 'life time counts' in order to focus on the impact of recent work and thus on current research performance. Accordingly, this article used a uniform citation window rather than entire citation counts. In addition, for the citation window, it would be preferable to take into account longer publication periods and a longer citation period (Peters & van Raan, 1994; Vinkler, 1988). Vinkler (1988) recommended five years instead of one or two years. Following his argument, we decided to use more than five years citation period. That is, this article calculated the citation counts of all articles with a uniform citation window of seven years (i.e. longer citation period), including the publication year. For instance, if an article published in 2003, its citation counts would be calculated from 2003 to 2009, keeping a window of seven years. The citations in 2010 will be excluded.

Table 3
Correlation matrix.

	CI	DC	CC	RCC	Degree centrality
CI	1				
DC	.695***	1			
CC	.886***	.943***	1		
RCC	.865***	.952***	.996***	1	
Degree centrality	.554***	.431***	.517***	.466***	1

*** $p < .001$.

4. Results and discussion

Table 3 illustrates the correlation matrix of the five measures and shows that each measure was significantly related to the other measures, indicating that the measures captured similar concepts. Although some of these measures were adapted or created over time by prior studies, the results indicate that they all represented the notion of research collaboration.

To examine which measure was the best predictor of research outcomes, several tests were conducted with ordinary least squares regression analysis (see Table 4). Because these measures were highly correlated, it was assumed that only one measure needed to be put into a regression model. More specifically, putting two or more highly correlated variables into a regression model will result in coefficient estimates that change erratically, which is called multicollinearity (Hair, Anderson, Tatham, & Black, 1998). A simple way to check multicollinearity is using the variance inflation factor (VIF) with a threshold of 5. For example, if the DC and CC were used as indicators in the regression model to examine the coefficients on research productivity, the VIF of these indicators would increase from 1 to 9, indicating the bias of multicollinearity. Therefore, in order to avoid multicollinearity, this study only puts an indicator into the regression model in each test.

As shown in Table 4, degree centrality was the best predictor, exhibiting the highest explanation (coefficient) on research productivity. The other measures (i.e. CI, DC, CC, and RCC) were not highly associated with research productivity, and even their associations were negative. A plausible explanation is that the equations of CI, DC, CC, and RCC were all divided by the total number of articles, which was treated as research productivity in this article. Therefore, based on the mathematical relationships, these causal associations were negative. In fact, according to the equations and definitions, these measures were not suitable for predicting research productivity, which is a major conclusion of this article.

Next, the RCC was the best predictor of the average JIF. However, in addition to RCC, the DC and CC also have significant and approximate coefficient with the average JIF. Accordingly, this article indicated that the DC, CC, RCC are all proper measures for predicting the average JIF. Moreover, the results showed that the DC and RCC were both significantly associated with average citations. Finally, it was found that the unit of analysis of degree centrality was different from the other measures. In fact, degree centrality has specific nature in measuring research collaboration, that is, it is concerned with collaborations within particular sets of authors. It refers to a scholar's formal power or prominence in the network relative to others (Burkhardt & Brass, 1990). Degree centrality (i.e. a scholar's number of direct ties to others) implies that scholars are well connected and have access to many alternative sources of knowledge and other resources (Walter, Lechner, & Kellermanns, 2007). Based on the definition of degree centrality, the unit of analysis is the scholar ('*individual*') in the network. However, the unit of analysis of the average JIF/citations is the '*article*', just as the average JIF represents the mean JIF per article. Therefore, to promote consistency between the units of analysis, this article included the coefficient of degree centrality on the JIF and citations aggregated from all of the articles by a given author, whose unit of analysis was aggregated JIF/citations

Table 4
Results of regression analysis.

	CI	DC	CC	RCC	Degree centrality
Research productivity					
Beta coefficient	−.139	−.129	−.150	−.205*	**.541*** **
F value	2.291	1.974	2.672	5.095*	**48.12*** **
R square	.019	.017	.023	.042	**.293**
Average JIF (JIF)					
Beta coefficient	.214*	.252**	.248**	**.273** **	.063 (.502***)
F value	5.591*	7.897**	7.63**	**9.196** **	.468 (39.06***)
R square	.046	.064	.062	**.073**	.004 (.252)
Average citations (citations)					
Beta coefficient	.064	**.219* **	.165	.188*	.114 (.153)
F value	.482	**5.827* **	3.255	4.257*	1.518 (2.769)
R square	.004	**.048**	.027	.035	.013 (.021)

Bold value represents the highest value among these five measures.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

Table 5
Results of comparative study.

	CI	DC	CC	RCC	Degree centrality
Calculation	Easy	Very easy	Middle	Middle	Difficult
Unit of analysis	Article	Article	Article	Article	Individual
Representative of research collaboration	Yes	Yes	Yes	Yes	Yes
Predictability of research productivity				Low	High
Predictability of average JIF	Low	Middle	Middle	Middle	
Predictability of average citations		Low		Low	

per scholar. Table 4 shows that the degree centrality had a positive and significant coefficient on the JIF ($B = .502$; $P < .001$) but an insignificant effect on the citations ($B = .153$; $P = .099$).

5. Conclusions

The purpose of this article was to conduct a comparative study of five collaborative measures that have been proposed by prior studies; the findings are summarized in Table 5. First, the calculation of degree centrality was relatively difficult because the collaborative relationships between the author and his or her co-authors needed to be collected, which required the use of SNA software. Second, as mentioned above, the unit of analysis of degree centrality was the individual, which was quite different from the other measures. However, it does not mean that degree centrality is inappropriate to use for future researchers. It is different in purpose. Degree centrality is a structural property measure and represents the number of co-authors linked with a scholar (Lu & Feng, 2009; Otte & Rousseau, 2002). High degree centrality means a person who directly linked with others, so he or she is likely to a sense of being in the mainstream of information flow in the network (Freeman, 1979). If researchers attempt to examine the collaboration pattern particular in authors' collaborative behavior, degree centrality is a most suitable measure rather than other measures.

Third, the empirical results showed that these five measures all captured a similar notion; that is, the degree of research collaboration. The results confirmed that all five of the measures are suitable for quantifying the degree of research collaboration, which corresponds to the assertions in prior studies.

It was determined that degree centrality was the best predictor of research productivity and that other measures were inappropriate due to the negative causal relationship after the calculation were made. However, the degree centrality had no effects on the average JIF or average citations. A plausible explanation for this is the unit of analysis: according to its unit of analysis, degree centrality is more suitable for the prediction of individual variables, such as research productivity and JIF.

Finally, the RCC and DC had the highest coefficient estimates for the average JIF and average citations, respectively. Overall, this article indicates that the RCC and DC are superior measures because they are not difficult to calculate by the researcher and have significant coefficients on both the average JIF and average citations. Except for research productivity, the RCC and DC possess many advantages over the other measures. In particular, for researchers who do not want to spend much time on calculations, the DC would be a good choice.

However, the five collaborative measures this study purposed are not exhaustive indicators which can be used to quantity the degree of research collaboration. For instance, Egghe (1991) presented a measure 'γ^*' which satisfies all the natural principles. Future research could expand the findings of this study by incorporating other measures. Additionally, the criteria applied to determine our research subjects (scholars) are using convenience sampling. For instance, we chose time periods at first and then determined research subjects. The prolific 118 scholars were determined by a given particular period, i.e. 1999–2004 or 1995–2004. However, there are many alternatives or time periods can be considered. Determining different time periods will have different research subjects. This convenience sampling approach may result in potential bias. Future research could improve this flaw by incorporating a more comprehensive approach.

Acknowledgements

The authors would like to thank the anonymous reviewers for their insightful comments and suggestions.

References

Ajiferuke, I., Burrell, Q. & Tague, J. (1988). Collaborative coefficient: A single measure of the degree of collaboration in research. *Scientometrics*, *14*(5/6), 421–433.

Bammer, G. (2008). Enhancing research collaborations: Three key management challenges. *Research Policy*, *37*(5), 875–887.

Borgatti, S. P., Everett, M. G. & Freeman, L. C. (1999). *UCINET 5.0 version 1.00*. Natick: Analytic Technologies.

Bouyssou, D. & Marchant, T. (2011). Bibliometric rankings of journals based on impact factors: An axiomatic approach. *Journal of Informetrics*, *5*(1), 75–86.

Burkhardt, M. E. & Brass, D. J. (1990). Changing patterns or patterns of change? The effects of a change in technology on social network structure and power. *Administrative Science Quarterly*, *35*(1), 104–127.

Clark, J. G. & Warren, J. (2006). In search of the primary suppliers of IS research: Who are they and where did they come from? *Communications of the Association for Information Systems*, *18*, 296–328.

Cronin, B., Shaw, D. & La Barre, K. (2004). Visible, less visible, and invisible work: Patterns of collaboration in 20th century chemistry. *Journal of the American Society for Information Science and Technology*, *55*(2), 160–168.

Eaton, J. P., Ward, J. C., Kumar, A. & Reingen, P. H. (1999). Structural analysis of co-author relationships and author productivity in selected outlets for consumer behavior research. *Journal of Consumer Psychology*, *8*(1), 39–59.
Egghe, L. (1991). Theory of collaboration and collaborative measures. *Information Processing & Management*, *27*(2/3), 177–202.
Freeman, L. C. (1979). Centrality in social networks: Conceptual clarifications. *Social Network*, *1*(3), 215–239.
Goldfinch, S., Dale, T. & DeRouen, K., Jr. (2003). Science from the periphery: Collaboration, networks and periphery effects in the citation of New Zealand Crown Research Institutes articles, 1995–2000. *Scientometrics*, *53*(3), 321–337.
Hair, J. F., Anderson, R. E., Tatham, R. L. & Black, W. C. (1998). *Multivariate data analysis* (5th ed.). Boston, MA: Pearson Education Inc.
Hauptman, R. (2005). How to be a successful scholar: Publish efficiently. *Journal of Scholarly Publishing*, *36*(2), 115–119.
Hudson, J. (1996). Trends in multi-authored papers in economics. *Journal of Economic Perspective*, *10*(3), 153–158.
Katz, J. S. & Hicks, D. (1997). How much is a collaboration worth? A calibrated bibliometric model. *Scientometrics*, *40*(3), 541–554.
Katz, J. S. & Martin, B. S. (1997). What is research collaboration? *Research Policy*, *26*, 1–18.
Lawani, S. M. (1980). *Quality, collaboration and citations in cancer research: A 268 bibliometric study*. Ph.D. Dissertation. Florida State University.
Lee, S. & Bozeman, B. (2005). The impact of research collaboration on scientific productivity. *Social Studies of Science*, *35*(5), 673–702.
Liu, X., Bollen, J., Nelson, M. L. & Van de Sompel, H. (2005). Co-authorship networks in the digital library research community. *Information Processing & Management*, *41*(6), 1462–1480.
López-Illescas, C., de Moya-Anegón, F. & Moed, H. F. (2008). Coverage and citation impact of oncological journals in the Web of Science and Scopus. *Journal of Informetrics*, *2*(4), 304–316.
Lu, H. & Feng, Y. (2009). A measure of authors' centrality in co-authorship networks based on the distribution of collaborative relationships. *Scientometrics*, *81*(2), 499–511.
Oh, W., Choi, J. N. & Kim, K. (2005). Coauthorship dynamics and knowledge capital: The patterns of cross-disciplinary collaboration in information systems research. *Journal of Management Information Systems*, *22*(3), 265–292.
Otte, E. & Rousseau, R. (2002). Social network analysis: a powerful strategy, also for the information sciences. *Journal of Information Science*, *28*(6), 441–453.
Peters, H. P. F. & van Raan, A. F. J. (1994). A bibliometric profile of top-scientists: A case study in Chemical engineering. *Scientometrics*, *29*(1), 115–136.
Ponomariov, B. L. & Boardman, P. C. (2010). Influencing scientists' collaboration and productivity patterns through new institutions: University research centers and scientific and technical human capital. *Research Policy*, *39*, 613–624.
Presser, S. (1980). Collaboration and the quality of research. *Social Studies of Science*, *10*(1), 95–101.
Rousseau, R. (2011). Comments on the modified collaborative coefficient. *Scientometrics*, *87*(1), 171–174.
Schloegl, C. & Stock, W. G. (2004). Impact and relevance of LIS Journals: A scientometric analysis of international and German-language LIS Journals—Citation analysis versus reader survey. *Journal of the American Society for Information Science and Technology*, *55*(13), 1155–1168.
Soderbaum, F. (2001). Networking and capacity building: The role of regional research networks in Africa. *European Journal of Development Research*, *13*(2), 144–163.
Sooryamoorthy, R. (2009). Do types of collaboration change citation? Collaboration and citation patterns of South African science publications. *Scientometrics*, *81*(1), 177–193.
Stillman, F. A., Wipfli, H. L., Lando, H. A., Leischow, S. & Samet, J. M. (2005). Building capacity for international tobacco control research: The global tobacco research network. *American Journal of Public Health*, *95*(6), 965–968.
Subramanyam, K. (1983). Bibliometric studies of research collaboration: A review. *Journal of Information Science*, *6*(1), 33–38.
Van Raan, A. F. J. (2006). Comparison of the Hirsch-index with standard bibliometric indicators and with peer judgment for 147 chemistry research groups. *Scientometrics*, *67*(3), 491–502.
Vinkler, P. (1988). An attempt of surveying and classifying bibliometric indicators for scientometric purposes. *Scientometrics*, *13*(5/6), 239–259.
Walter, J., Lechner, C. & Kellermanns, F. W. (2007). Knowledge transfer between and within alliance partners: Private versus collective benefits of social capital. *Journal of Business Research*, *60*(7), 698–710.
White, H. D. & McCain, K. W. (1998). Visualizing a discipline: An author co-citation analysis of Information Science, 1972–1995. *Journal of American Society of Information Science*, *49*(4), 327–355.