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A comparison of 17 article-level bibliometric indicators of institutional research productivity: Evidence from the information management literature of China

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ABSTRACT

Periodically ranking institutional research productivity is necessary not only to understand the status of the development of related fields but also to identify gaps and take appropriate corrective steps. Many bibliometric indicators contribute to the assessment of institutional research productivity, but the appropriateness of the indicator and the relationships between different indicators are topics that have not been addressed. For this reason, an indicator framework for the ranking of institutional research performance, which consists of a count of published articles and quality weighted dimensions, is developed. Based on the literature review, 17 indicators in the framework are chosen for study. Based on these indicators, experiments are conducted to rank Chinese institutions in the field of Information Management. Kendall's tau rank correlation coefficient (τ) is calculated, and all pairwise correlations are between 0.34 and 0.98. There are three primary findings: (1) among the article count indicators, the Straight count indicator is significantly different than others; (2) the rankings based on the indicators which are weighted by quality are consistent with those based on the indicators using article count; and (3) the Paper citation weighted indicator is sensitive to the procedure used for institutional ranking.

1. Introduction

Ranking the institutional research productivity has become increasingly important because rankings can influence the reputation of an organization or a university and affect its ability to raise funds (Beaulier, Elder, Han, & Hall, 2016; Lahiri & Kumar, 2012). Rankings of institutional research productivity can be based on many factors: peer-review surveys, research (works, citations), teaching, the size of the institution and number of faculty members, acquisition of grants, etc. The collective faculty output can be used to rank an institution. Existing ranking methods focus on research output and can be divided into two types: the article count method and the quality-weighted method.

The article count method reflects the output quantity of an institution and is obtained by counting publications (Hou, Fan, & Liu, 2014; Xu, Yalcinkaya, & Seggie, 2008). Because of increased cooperation among institutions, multiple affiliations

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are common. Some researchers suggest that each institution receive credit for the shared work, while others assert that only the first institution should receive credit (Dridi, Adamowicz, & Weersink, 2010; Jin & Hong, 2008). Therefore, if authors from multiple institutions wrote an article, how should scores be assigned to each institution? Chua et al. identified four article count indicators, including Normal count, Weighted count, Adjusted count, Straight count and Weighted page count (Chua, Cao, Cousins, & Straub, 2002). However, their research does not explain the difference between indicators nor identify which are appropriate for the assessment of institutional research productivity.

In contrast, the quality weighted method emphasizes the content and quality of published works (Xu et al., 2008). As opposed to counting published works, the quality weighted method incorporates a quality element that reflects the content of the paper (Xu, Chan, & Chang, 2016). There is a consensus that citations are quality indicators (Hou et al., 2014; Peng & Zhou, 2006; Xu et al., 2016). In addition, indicators such as Journal pages, Journal rating, and Standardized words are used to assess quality (Chan, Chen, & Steiner, 2001; Wu, Li, Zhu, Song, & Li, 2015; Yu & Gao, 2010). Hirsch's *h* is the most well-known hybrid index that combines the number of publications and number of citations to measure researcher output (Hirsch, 2005). Additionally, it is used to rank institutions and to measure the academic success of an institution in a given subject area (Schubert, Glänzel, & Braun, 2008; Turaga & Gamblin, 2012). Molinari and Molinari, (2008) devised the impact index (*i*), based on the *h*-index, to evaluate institutional research productivity. Additionally, similar studies have used the *h*-index and impact index to rank universities, laboratories, and government agencies (Hendrix, 2008). Although effective and simple, the *h*-index has limitations. Consequently, improved *h*-type indexes were proposed to overcome these limitations (Burrell, 2007; Egghe, 2006; Iglesias & Pecharromán, 2007; Jin et al., 2007; Liang, 2006).

Most ranking studies include incongruous and incomparable methods (Kaur, Ferrara, Menczer, Flammini, & Radicchi, 2014; Moed & Gali, 2015). Some studies use article counts instead of publication quality, while others use citations but ignore the accuracy of article counts. Importantly, these methods may be similar but distinct constructs. Do all bibliometric indicators result in the same outcome, i.e., measuring institutional research productivity? Are there valid and applicable indicators? The relationship between the commonly used indicators remains unexplained.

Information Management research addresses phenomena related to planning, developing, implementing, maintaining, using and managing information systems (Banker & Kauffman, 2004). Unlike other research disciplines, Information Management is a discipline in which research and practice are closely intertwined and evolve from several related disciplines (Grover, 2012). In the field of Information Management, several papers that were published since 2000 have focused on evaluating the research productivity of researchers, but only a small portion of the studies have focused on institutional productivity. In the literature, there are two primary findings regarding methods used to rank institutions. On the one hand, much of the research has ranked institutions using article counts rather than publication quality. However, the quality of an article is critical. On the other hand, research in the context of China is sparse. Most studies regarding the state of Information Management research have been performed in the U.S. and the results might not be fully applicable to China. Importantly, the nature of the academic institutions in both countries is different. Therefore, the Information Management research productivity of Chinese institutions should receive more attention.

The objective of this paper is to compare the article-level indicators for ranking institutions through a study of Chinese institutions in the field of Information Management. We aim to discover the following: 1) the most common bibliometric indicators used in the assessment of institutional research productivity, 2) the correlation between article count indicators and quality weighted indicators, and 3) which indicators are sensitive to the procedure used for institutional ranking. This paper makes two contributions. First, it proposes an indicator framework that provides a complete and reliable review of the institutional ranking indexes that take into account article counts and research quality. To the best of our knowledge, it is the first study to review institutional ranking indicators. The framework found 30 ranking methods that provide a reference for researchers, to guide research and enable new methods to be easily integrated. Second, we compare the rankings, based on the value of 17 ranking indicators of 1702 institutions in the field of Chinese Information Management. In addition, we compare the correlation coefficients among these ranking indicators to assess the existing ranking methods and determine which metrics are applicable to the measurement of institutional research productivity.

The remainder of this article is structured as follows. The second section presents extant indicators that are widely used to rank institutions and proposes an indicator framework. The third section presents the data collection and analysis procedures. The impact of each indicator on institutional ranking and a comparison of indicators are presented in the fourth section, while the findings and discussion are expounded upon in the fifth section. The sixth section explains limitations to the research. Finally, the seventh section discusses the conclusions reached through the study.

2. Review of institutional ranking methods

This study identifies extant indicators that are widely used to rank institutions. As shown in Table 1, we identify ten core indicators that consist of five article count dimensions and five quality-weighted dimensions. The five article count dimensions examine the number of articles and include Publication count, Normal count, Straight count, Adjusted count, and Real count. The five quality-weighted dimensions evaluate the quality of publications and include the Impact factor, Journal page, Paper citation, Journal rating, and Standardized word. These indicators are chosen because they are simple to calculate and are suitable for the use of correlational significance tests to evaluate their applicability. Because the *h*-index is a hybrid index, we did not include it in Table 1. A hybrid index recomposes the mathematical properties of the indicator to produce a single measure of productivity and effect (Wildgaard, 2015). The mathematical properties of the indicators in

Table 1
The ten core indexes used to rank institutions and the concepts that they measure.

No.	Core index	Definition	Index type
1	Publication count (Hou et al., 2014)	When an institution appears more than once, it is only counted one time.	Article count
2	Normal count (Chua et al., 2002)	Each institution is calculated according to how many times it appeared in articles.	Article count
3	Straight count (Jin & Hong, 2008)	The first institute of the first author receives the score.	Article count
4	Adjusted count (Xu et al., 2008)	If an article has contributions from N institutes, each institute will receive a score of 1/N.	Article count
5	Real count (Chan et al., 2006)	If an article has N authors and M institutions, each affiliated institution receives a score of 1/MN.	Article count
6	Impact factor (Dridi et al., 2010)	The ratio of the number of citations in a journal to the number of articles published in the journal over a fixed period.	Quality weighted
7	Journal page (Yu & Gao, 2010)	The average number of pages per article in a publication.	Quality weighted
8	Paper citation (Chan et al., 2011)	The number of times a paper is cited in other papers.	Quality weighted
9	Journal rating (Wu et al., 2015)	The rating score of a journal in the ABS Journal Guide.	Quality weighted
10	Standardized word (Chan et al., 2001)	The number of pages per article multiplied by the number of words in a standard page of a journal. A standard page includes words, not equations, tables and figures.	Quality weighted

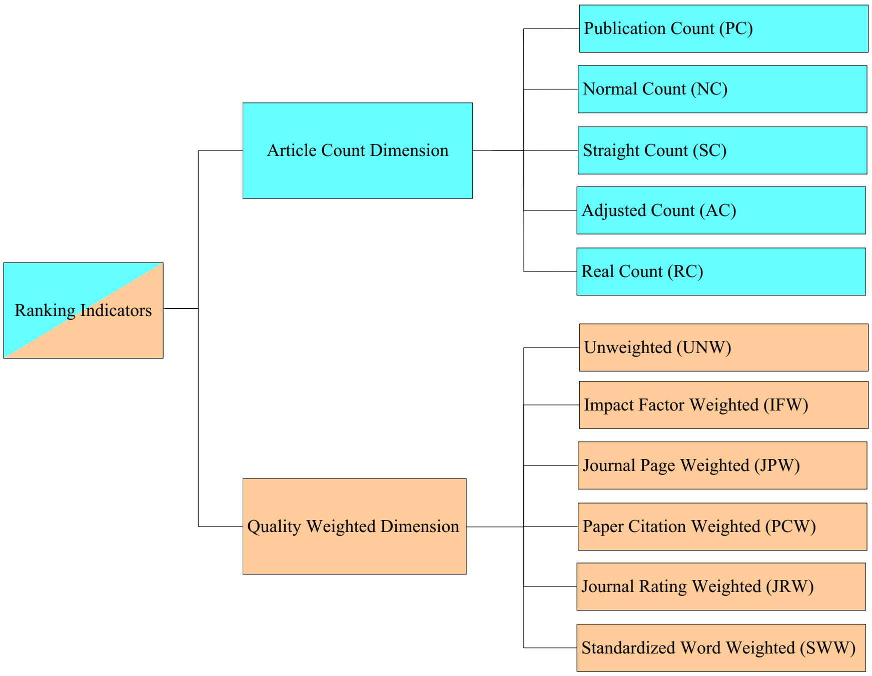

Fig. 1. Indicator framework for institutional ranking research.

Table 1 are presented, and the indicator is used to count the quantity of articles or as a quality element used weigh the article count.

Additionally, we develop an indicator framework to identify all possible ranking methods. As shown in Fig. 1, institutional ranking indicators are combined using the article count and quality weighted indexes.

Importantly, because the index that includes only weighted counts of published works assumes that the total score of an article is 1, it has no quality weight. Therefore, the framework uses 30 indicators to rank institutions. Because the focus of researchers differs, indicators in different articles may be in different positions within the framework. Among these indicators, 17 are widely used in the literature. Table 2 provides an overview of these indicators and references. Each indicator that starts with “UNW-” is an unweighted quality index. The five indicators that count the number of articles are UNW-PC, UNW-NC, UNW-SC, UNW-AC, and UNW-RC. The weighting scales for article count include two recursive impact factor indicators, IFW-PC and IFW-RC; two recursive Journal page indicators, JPW-AC and JPW-RC; three recursive Paper citation indicators, PCW-PC, PCW-AC, and PCW-RC; two recursive Journal rating indicators, JRW-SC and JRW-RC; and three recursive Standardized word indicators, SWW-PC, SWW-AC, and SWW-RC. Together, they are the 17 bibliometric indicators we use to analyze the mathematical properties of indexes.

(1) **Unweighted publication count indicator (UNW-PC)**
The Publication count index is the simplest method used to rank institutions. If an article is affiliated with one or

Table 2
Indicator framework in the institutional ranking.

Article count quality weighted	Publication count (PC)	Normal count (NC)	Straight count (SC)	Adjusted count (AC)	Real count (RC)
Unweighted (UNW)	UNW-PC (Malhotra & Kher, 1996)	UNW-NC (Chua et al., 2002)	UNW-SC (Jin & Hong, 2008)	UNW-AC (Athey & Plotnicki, 2000)	UNW-RC (Shim, English, & Yoon, 1991)
Impact factor weighted (IFW)	IFW-PC (Dridi et al., 2010)				IFW-RC (Hou et al., 2014)
Journal page weighted (JPW)				JPW-AC (Coupé, 2003)	JPW-RC (Yu & Gao, 2010)
Paper citation weighted (PCW)	PCW-PC (Fu & Ho, 2013)			PCW-AC (Lowry et al., 2004)	PCW-RC (Chan et al., 2011; Hardin III et al., 2006)
Journal rating weighted (JRW)			JRW-SC (Babbar et al., 2000)		JRW-RC (Wu et al., 2015)
Standardized word weighted (SWW)	SWW-PC (Chan et al., 2001)			SWW-AC (Cheng et al., 2003)	SWW-RC (Chan et al., 2005)

more institutions, each institution receives a score of one (Dridi et al., 2010; Fu & Ho, 2013; Hou et al., 2014). When an institution appears more than once, the institution is still counted only once. The following equation can be used to calculate the indicator:

$$\mathrm{UNW-PC}_j = \sum_{i=1}^{n} C_{ij} \tag{1}$$

where C_{ij} is an index and n is the total number of articles. If an institution, j, is affiliated with an article, i, then $C_{ij} = 1$, otherwise $C_{ij} = 0$.

(2) **Unweighted normal count indicator (UNW-NC)**
The Normal count calculates institutional productivity by counting how many times it appeared in articles. Institutions receive a full score for any work in which they participate (Huang & Hsu, 2005). This index is different from the Publication count, in which the institution is only counted once for each article. Therefore, a more appropriate term for normal count could be simple count (Chua et al., 2002).

(3) **Unweighted straight count indicator (UNW-SC)**
The Straight count indicator scores only the first institute of the first author. It is assumed that every article is equivalent and that the first institute of the first author is solely responsible for idea creation (Chang & Hsieh, 2008; Jin & Hong, 2008).

(4) **Unweighted adjusted count indicator (UNW-AC)**
The Adjusted count indicator takes into account the contributions from multiple institutions. If an article has contributions from N institutes, each institute will receive a score of 1/N (Lahiri, 2011; Xu et al., 2008).

(5) **Unweighted real count indicator (UNW-RC)**
The Real count indicator adjusts for multiple affiliations and multiple authorships (Chan, Fung, & Leung, 2006; Wu et al., 2015). If an article has N authors, each author receives a score of 1/N. An author may be a member of M institutions and, therefore, each affiliated institution receives a score of 1/MN. Several authors may belong to the same institution. Therefore, the final score of an institution is the accumulated score of each author. Thus, this indicator is computed as follows:

$$\mathrm{UNW\ -\ RC}_j = \sum_{i=1}^{n} \sum_{m=1}^{a_i} C_{imj} \frac{1}{a_i K_{mi}} \tag{2}$$

When an article, i, has a_i authors and author m is affiliated with km_i institutions, then the author m has contributed $1/a_i km_i$ of the article for every institution. In Eq. (2), if author m of an article i is affiliated with institution j, then $C_{imj} = 1$, otherwise $C_{imj} = 0$. If there is more than one author from an institution, the contribution of all such authors is summed. Finally, the contribution of all articles is summed.
The relationship between authors and institutions in the Web of Science (WoS) database is not clear with respect to data entered prior to 2007. Therefore, while ranking, we assume that each institution has contributed equally to papers published before 2007. After 2008, the relationship between authors and institutions is clear and Eq. (2) is applied to calculate the Real count index.

(6) **Impact factor weighted publication count indicator (IFW-PC)**
This indicator is calculated using the Publication count indicator weighted by the Impact factor. While the quality of a publication is very important, the "UWN-" indicators do not account for quality. The Impact factor, which is the ratio of the number of citations from a given journal to the number of articles published in the journal over a fixed period, 5-years in SSCI, is used to adjust for the number of publications. Dridi et al. (2010) rank agricultural economics departments in Canada based on research output as measured by the Impact factor and Publication count indicator. The indicator can be calculated as follows:

$$\mathrm{IFW-PC}_{\ j} = \sum_{i=1}^{n} C_{ij} F_i \tag{3}$$

where F_i is the impact factor of the journal in which paper i is published.

(7) **Impact factor weighted real count indicator (IFW-RC)**
This indicator is calculated using the Real count weighted by the Impact factor. Hou et al. (2014) rank management schools in Greater China (including Mainland China, Hong Kong, Taiwan, and Macau) using the Real count and number of articles published, weighted by the Impact factor. Therefore, the indicator is computed as follows:

$$\mathrm{IFW-RC}_j = \sum_{i=1}^{n} \sum_{m=1}^{a_i} C_{imj} \frac{1}{a_i K_{mi}} F_i \tag{4}$$

(8) **Journal page weighted real count indicator (JPW-RC)**
This indicator is calculated using the Real count weighted by the Journal page. The ranking indicator assumes that paper length is a quality-weighted index. For instance, Chinese institutions published 322 papers in *Computers in Human Behavior*, which equals 7.7% of total publications. However, the papers in *Computers in Human Behavior* are usually no longer than 9 pages. Short papers have less content, therefore, researchers suggest the use of JPW to adjust for the content quantity. In this study, the pages of each article can be obtained from the WoS database, then, the average number of pages per article in the publication is calculated to construct this indicator. Yu et al. (2010) rank economic research institutions in China based on Real count, Journal page weighted index and 6 other indexes. The indicator can be calculated as follows:

$$\mathrm{JPW-RC}_j = \sum_{i=1}^{n} \sum_{m=1}^{a_i} C_{imj} \frac{1}{a_i K_{mi}} G_i \tag{5}$$

where G_i is the number of pages in publication i.

(9) **Journal page weighted adjusted count indicator (JPW-AC)**
This indicator is calculated using Adjusted count and weighted by Journal page. Coupé (2003) studies the academic research of economics departments using this method, which is based on Paper citation, Journal page and Adjusted count.

(10) **Paper citation weighted publication count indicator (PCW-PC)**
This indicator is calculated using Publication count and weighted by Paper citation. Publication count can be obtained from the WoS database. Fu et al. (2013) compare the institutionally independent publications of Tsinghua University and Peking University using two indicators, publications and citations. The indicator can be calculated as follows:

$$\mathrm{PCW-PC}_{\ j} = \sum_{i=1}^{n} C_{ij} W_i \tag{6}$$

where W_i is the citation of article i.

(11) **Paper citation weighted real count indicator (PCW-RC)**
This indicator is calculated using the Real count and weighted by Paper citation. Because of the mathematical properties of the Real count indicator, the citation index should be divided by the number of authors (Chan, Chen, & Lee, 2011; Hardin III, Liano, & Chan, 2006). For example, consider a three-author article by author A at X Institution, author B at Y Institution, and author C at Z Institution, that has been cited 30 times. For this publication, the citation index for X Institution is calculated as 1/3 times 30, which gives an index of 10. The indicator can be computed as follows:

$$\mathrm{PCW-RC}_j = \sum_{i=1}^{n} \sum_{m=1}^{a_i} C_{imj} \frac{1}{a_i K_{mi}} W_i \tag{7}$$

(12) **Paper citation weighted adjusted count indicator (PCW-AC)**
This indicator is calculated using Adjusted count weighted by Paper citation. Lowry, Romans, and Curtis (2004) use Paper citation and Adjusted count to provide an assessment of the impact of articles on and the productivity of researchers and institutions in the field of Information Management.

(13) **Journal rating weighted real count indicator (JRW-RC)**
This indicator is calculated using Real count weighted by Journal rating. Wu et al. (2015) proposed a Journal rating adjusted publication (JRAP) index to assess the quality of journals in the field of Business and Management. The indicator can be calculated as follows:

$$\mathrm{PCW} - \mathrm{RC}_j = \sum_{i=1}^{n} \sum_{m=1}^{a_i} C_{imj} \frac{1}{a_i K_{mi}} \mathrm{journal} - \mathrm{rate}_i \tag{8}$$

For this indicator, we use the rating score of a journal to adjust for the quality of articles. We select journals rated 2 or above to adjust for the quality of publications. For instance, if a journal is rated 2 in the ABS Journal Guide, its journal-rate is 0.5. In addition, if the journal is rated 3, the journal-rate will be 1. The journal ratings of the experimental publications are shown in "Appendix".

(14) **Journal rating weighted straight count indicator (JRW-SC)**
This indicator is calculated using Straight count and weighted by Journal rating. Babbar, Prasad, and Tata (2000) calculate the quality ratings of a set of journals and use the number of articles as an indicator to assess institutional and individual research productivity in the field of International Operations Management.

(15) **Standardized word weighted publication count indicator (SWW-PC)**
This indicator is calculated using Publication count weighted by Standardized word. Chan et al. (2001) proposed a JF-equivalent typical page count index to adjust for both quantity and quality. JF is an abbreviation for the Journal of Finance. A standard journal page includes only words, not equations, tables, or figures. For example, if there are 517 words on a standard page of the *Journal of Financial Economics* and 544 words in the *Journal of Finance*, the total word count of the *Journal of Financial Economics* is converted to JF-equivalent pages by the adjustment factor 0.9504 (i.e., 517 divided by 544). The indicator facilitates the comparison of articles published in different journals with different styles and layouts. In this study, we select a standard page of each journal and count the number of words. The number of pages per article multiplied by the number of words is the standardized word count. The indicator is computed as follows:

$$\mathrm{SSW} - \mathrm{PC}\ _j = \sum_{i=1}^{n} C_{ij} S_i \tag{9}$$

where S_i is the standardized number of words of article i in a publication.

(16) **Standardized word weighted adjusted count indicator (SWW-AC)**
This indicator is calculated using Publication count and weighted by Standardized word count. Cheng, Chan, and Chan (2003) use a weighted *Journal of Marketing*-equivalent page count to account for differing font and page sizes, differing article lengths, and, in addition, the Adjusted Count index is used to examine research productivity of Asia-Pacific universities in the field of marketing.

(17) **Standardized word weighted real count indicator (SWW-RC)**
This indicator is calculated using Real count and weighted by Standardized word. Chan et al. use Adjusted count and the JF-equivalent page count index to provide a ranking of finance programs and institutions in the Asia-Pacific region (Chan, Chen, & Cheng, 2005). The indicator can be calculated as follows:

$$\mathrm{SWW} - \mathrm{RC}_j = \sum_{i=1}^{n} \sum_{m=1}^{a_i} C_{imj} \frac{1}{a_i K_{mi}} S_i \tag{10}$$

3. Data and methods

3.1. Data collection

This study uses Information Management journals from the Academic Journal Guide of the Association of Business Schools (ABS Journal Guide) to rank Information Management research institutions in China (Hussain, 2013). The reasons for selecting the ABS Journal Guide are 1) The ABS Journal Guide is based on peer reviews, editorials and expert judgments of hundreds of publications and is informed by statistical information relating to citations (Thomas, Morris, Harvey, & Kelly, 2009); 2) The field of Information Management in the journal lists of the guide reflect the perceptions of the editors, the scientific committee, and expert peers. Therefore, it is a tool that can be used to distinguish between Information Management and other disciplines; 3) The ABS Journal Guide provides quality ratings of 4*, 4, 3, 2, and 1.

We selected 52 journals, rated 2 or above, from the ABS Journal Guide to rank institutions in the field of Information Management. Because of the Impact factor used in this study, we selected 42 journals indexed by the WoS as the dataset. The information of the 42 journals listed in the ABS journal guide, that were rated 2 or above, is listed in the Appendix.

The search includes articles published from 2001 to 2015. The search query is "SO= ("Information Systems Research" OR "MIS Quarterly" OR …) AND AD= (Peoples R China)". From the search, full records of the journal, including the author, title, source and abstract of each paper are obtained from the WoS database. The document type is Article. A total of 4181 papers were identified.

Because the data in the WoS database is stored, the raw data obtained from the WoS database have several problems that had to be addressed manually. First, the abbreviations of the name of an institution may vary widely from author to author, and the English names of institutions are not unique. For example, "Beihang Univ" and "Beijing University of Aeronautics and Astronautics" are the same institution but have different names in the WoS database. To solve this problem, we consolidated all abbreviations of the name of an institution into one name. Second, in 2014, the journal, *Journal of the American Society for Information Science and Technology,* changed its name to the *Journal of the Association for Information Science and Technology*. We manually included the data from *Journal of the Association for Information Science and Technology* for 2014 and 2015. Third, the country term is standardized in the WoS database, except for those that end with Hong Kong. We changed them to China.

3.2. Method

The Kendall's tau rank correlation coefficient (τ) is used to explore the significant relationship between each pair of indicators. Kendall's τ is a non-parametric coefficient and is appropriate for the skewed data used in this paper, such as those of citations. Moreover, Kendall's τ is widely used to compare multiple bibliometric indicators. For example, Wildgaard and Finardi used Kendall's τ to compare bibliometric indicators (Finardi & Finardi, 2013; Wildgaard, 2015). The Kendall's τ coefficient is defined as follows:

$$\tau = \frac{(\text{number of concordant pairs}) - (\text{number of discordant pairs})}{n(n-1)/2} \quad (11)$$

The denominator is the total number of pair combinations. Therefore, the coefficient must be $-1 \leq \tau \leq 1$. If the agreement between the two rankings is perfect (i.e., the two rankings are the same), then the coefficient takes a value of 1. If the disagreement between the two rankings is perfect (i.e., one ranking is the reverse of the other) then the coefficient takes a value of -1. If the rankings are independent, then we expect the coefficient to be approximately zero.

4. Empirical results

This section first provides descriptive statistics for the bibliometric indicators used to analyze Chinese institutions in the field of Information Management. The impact of each indicator on the rankings of institutions and the changes in the rankings are mapped. In the next section, the general indicators are used in a Kendall's τ analysis, and each pair of indicators is compared. Then, using article count, five indicators that are not weighed by quality are compared in pairs. Additionally, the impact of each indicator on the institutional ranking is reported. With regard to quality weighting, the other 12 indicators, weighted by Impact factor, Journal pages, Paper citations, Journal rating and Standardized word, are compared and the significant impact on institutional rankings is reported.

4.1. A descriptive look at the ranking indicators

Before discussing ranking calculations, we provide descriptive statistics of the bibliometric indicators. We obtained a dataset from the WoS and calculated all 17 indicators for 1702 Chinese institutions. Table 3 shows the descriptive statistics for each indicator, including the number, mean, median, standard deviation, and, minimum and maximum values of the institutions.

Based on these results, we calculate the rankings of institutions. We include all indicators. Table 4 shows the top 20 Chinese institutions across all 17 bibliometric indicators. These comparative rankings indicate small changes in the relative positions across the indicators, except for the PCW-PC, PCW-AC, and PCW-RC. As shown in Table 4, City University of Hong Kong, Hong Kong Polytech University, Tsinghua University, Chinese Academy of Sciences and The University of Hong Kong are the top 5 institutions. However, this ranking changes significantly when the Paper citation weighted indicator is included. The Chinese Academy of Sciences is ranked 9th when the PCW-PC is used, while The University of Hong Kong is ranked 9th when the PCW-AC or PCW-RC are used. The second analysis is reported in the following section.

4.2. Comparison of ranking indicators

Every correlation coefficient that matches two variables is calculated using Kendall's τ method (Table 5). A correlation matrix (Fig. 2) with correlation coefficients is constructed using the MATLAB scientific project calculation software.

Among the indicators, the UNW-SC, UNW-AC, UNW-RC, JPW-AC, JPW-RC, JRW-SC, SWW-AC, and SWW-RC have a weak correlation with the PCW-PC, <0.40. However, there is a strong correlation between the PCW-PC and the PCW-AC and between the PCW-AC and PCW-RC (0.8 and 0.9, respectively). The quality weighted metrics are strongly correlated between the SWW-RC and JPW-RC and between the SWW-AC and JPW-AC (0.84 and 0.80, respectively). Additionally, the IFW-RC and

Table 3
Descriptive statistics for 1702 institutions for each indicator.

Ranking indicators	No.	Mean	Median	SD	Min	Max
UNW-PC	1702	5.35	1.00	22.75	1.00	584.00
UNW-NC	1702	5.76	1.00	24.76	1.00	624.00
UNW-SC	1702	2.46	0	12.78	0	270
UNW-AC	1702	2.46	0.50	12.09	0.02	282.25
UNW-RC	1702	2.46	0.50	12.55	0	288.15
IFW-PC	1702	12.19	3.00	52.32	0.42	1374.88
IFW-RC	1702	5.55	0.98	28.70	0.02	678.63
JPW-AC	1702	31.77	6.09	161.05	0.18	4080.86
JPW-RC	1702	31.78	5.49	166.79	0.05	4171.18
PCW-PC	1702	69.37	10	394.75	0	11,641.00
PCW-AC	1702	31.97	3.00	208.33	0	5907.25
PCW-RC	1702	31.97	2.75	212.68	0	6003.49
JRW-SC	1702	4.26	0	22.56	0	500
JRW-RC	1702	4.26	0.73	22.22	0	537.87
SWW-PC	1702	67,889.94	15,566.92	291,543.28	4662.89	7,590,117.00
SWW-AC	1702	31,020.66	6605.29	153,165.42	139.27	3,606,073.50
SWW-RC	1702	31,028.84	5357.15	159,220.95	37.92	3,699,711.80

No.= total number of Chinese institutions in the field of Information Management. SD=the standard deviation of 1702 institutions calculated from an indicator.

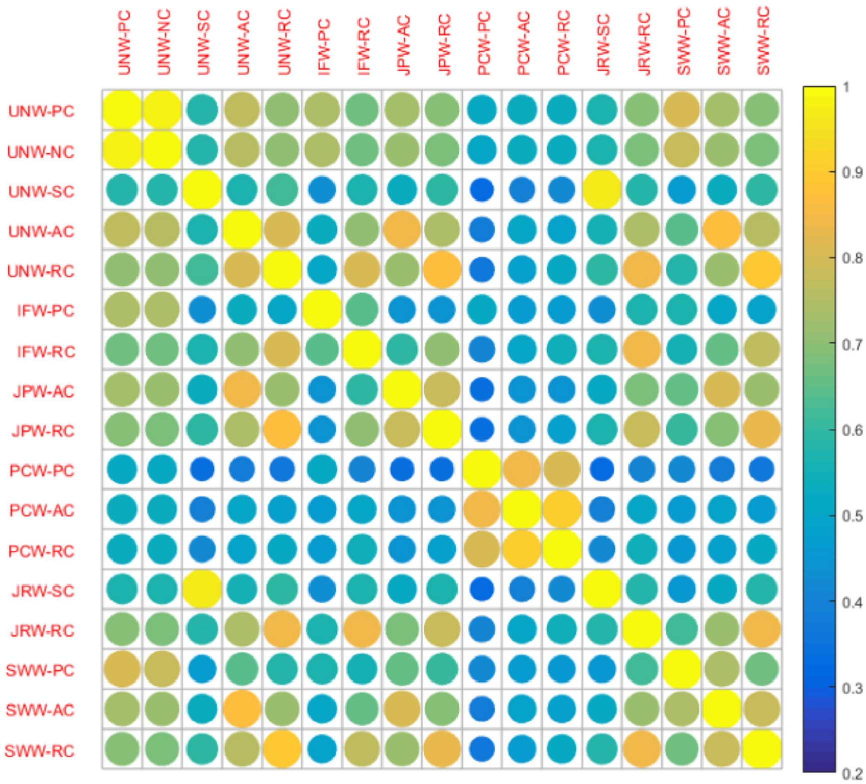

Fig. 2. Correlation matrix of 17 measures. Numbers that range from −1 to 1 are Spearman's rank correlation coefficients of variables on the horizontal and vertical axes. Color depth and the size of the circles indicate the relationship strength.

JRW-RC are highly correlated (0.85). Some correlation coefficients between article count indicators and quality weighted indicators are high, including the JPW-AC and UNW-AC (0.85), the JPW-RC and UNW-RC (0.87), the JRW-SC and UNW-SC (0.97), the JRW-RC and UNW-RC (0.84), the SWW-PC and UNW-PC (0.8), the SWW-AC and UNW-AC (0.87) and the SWW-RC and UNW-RC (0.89). Moreover, one of the Impact Factor weighted indicators, the IFW-RC, is strongly correlated with the UNW-RC (0.81).

The article count indicators, UNW-PC, UNW-NC, UNW-AC and UNW-SC and UNW-RC, are compared in pairs. Among the indicators, the UNW-PC has a strong correlation with the UNW-NC (0.98) and the UNW-AC has a strong correlation with the UNW-RC (0.81). In Fig. 2, the horizontal and vertical axes of the UNW-SC have deeper colors and smaller circles, which indicates that the UNW-SC correlates moderately with the other 4 indicators. This is evident from the institutional ranking results (Table 4). Based on the UNW-PC, UNW-NC, UNW-AC and UNW-RC, City University of Hong Kong and Hong Kong

Table 4
Top 20 institutions in the field of Information Management in China as calculated using 17 indicators.

Institutions	UNW-PC	UNW-NC	UNW-SC	UNW-AC	UNW-RC	IFW -PC	IFW -RC	JPW -AC	JPW -RC	PCW-PC	PCW-AC	PCW -RC	JRW -SC	JRW -RC	SWW-PC	SWW-AC	SWW-RC
City University of Hong Kong	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hong Kong Polytech University	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Tsinghua University	3	4	3	3	3	4	3	3	3	5	5	4	3	3	4	3	3
Chinese Academy of Sciences	4	3	4	4	4	3	4	4	4	9	4	5	4	4	3	4	4
The University of Hong Kong	5	5	6	5	6	5	6	5	5	4	9	9	6	6	5	7	7
Huazhong University of Sci & Technol	6	6	7	7	7	6	5	7	6	3	3	6	7	7	7	5	6
Shanghai Jiao Tong University	7	7	5	6	5	8	7	6	7	6	6	3	5	5	6	6	5
Chinese Univ Hong Kong	8	8	12	8	8	9	8	8	8	17	7	7	12	8	9	8	8
Hong Kong University of Sci & Technol	9	9	8	9	12	7	12	9	9	11	17	17	8	9	8	9	12
Fudan University	10	10	11	11	11	10	9	10	10	7	11	11	10	12	10	13	10
Xi'an Jiaotong University	11	11	10	12	10	12	10	12	12	8	8	8	9	10	11	11	13
Zhejiang University	12	12	16	13	13	11	11	11	11	14	19	19	11	11	13	10	9
Beihang University	13	13	13	10	9	14	16	13	13	13	14	14	19	13	12	12	11
University of Sci & Technol of China	14	14	19	16	16	13	13	15	16	10	16	16	18	18	15	15	16
Peking University	15	15	9	15	15	16	15	16	15	16	13	13	16	16	14	16	15
Harbin Institute of Technology	16	16	18	14	18	15	18	14	14	19	148	12	13	15	16	19	18
Hong Kong Baptist University	17	17	14	19	14	17	19	18	18	18	18	18	14	19	19	18	19
Dalian University of Technology	18	18	15	18	19	19	14	19	19	21	12	148	21	14	18	14	14
Southeast University	19	19	21	17	21	18	21	21	21	25	10	10	15	21	20	21	21
Nanjing University	20	20	17	21	17	21	17	17	17	51	21	21	17	17	21	17	17

In this table, there is a pattern in the rankings when the UNW-PC indicator is used. Overseas institutions are excluded.

Table 5
Kendall's correlations between 17 bibliometric indicators.

Indicators	UNW-PC	UNW-NC	UNW-SC	UNW-AC	UNW-RC	IFW-PC	IFW-RC	JPW-AC	JPW-RC	PCW-PC	PCW-AC	PCW-RC	JRW-SC	JRW-RC	SWW-PC	SWW-AC	SWW-RC
UNW-PC	1																
UNW-NC	0.98	1															
UNW-SC	0.58	0.58	1														
UNW-AC	0.77	0.76	0.57	1													
UNW-RC	0.71	0.70	0.62	0.81	1												
IFW-PC	0.75	0.74	0.44	0.53	0.50	1											
IFW-RC	0.67	0.67	0.57	0.71	0.81	0.65	1										
JPW-AC	0.74	0.72	0.54	0.85	0.72	0.44	0.60	1									
JPW-RC	0.69	0.69	0.59	0.74	0.87	0.44	0.70	0.78	1								
PCW-PC	0.52	0.52	0.34	0.38	0.37	0.52	0.41	0.34	0.34	1							
PCW-AC	0.54	0.53	0.39	0.50	0.48	0.47	0.50	0.45	0.44	0.84	1						
PCW-RC	0.54	0.53	0.42	0.50	0.52	0.47	0.55	0.44	0.48	0.80	0.90	1					
JRW-SC	0.56	0.56	0.97	0.55	0.60	0.44	0.56	0.52	0.58	0.34	0.39	0.42	1				
JRW-RC	0.69	0.68	0.58	0.74	0.84	0.57	0.85	0.68	0.78	0.41	0.51	0.55	0.59	1			
SWW-PC	0.80	0.78	0.47	0.65	0.58	0.57	0.56	0.66	0.60	0.42	0.47	0.46	0.46	0.62	1		
SWW-AC	0.73	0.71	0.53	0.87	0.72	0.51	0.66	0.80	0.70	0.38	0.49	0.48	0.52	0.72	0.75	1	
SWW-RC	0.69	0.69	0.59	0.76	0.89	0.49	0.77	0.72	0.84	0.37	0.47	0.51	0.58	0.84	0.67	0.79	1

All pairwise correlations are significant at a= 5%, two sided, and have a critical value $= \pm 1.96$. Kendall's tau (τ) takes values between -1 and $+1$, in which, for perfect agreement, $\tau = 1$ and for no association, $\tau = 0$. A positive correlation indicates that the ranks of the variables increase together while a negative correlation indicates that, as the rank of one variable increases, the other decreases.

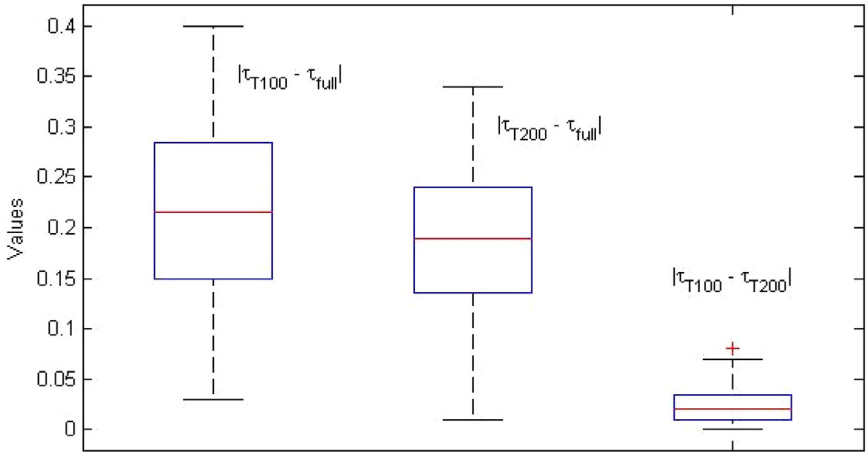

Fig. 3. Boxplot of the absolute coefficient difference of different indicator from Top 100, Top 200 and full datasets.

Polytech University are the top two institutions. This ranking is reversed when the UNW-SC indicator is included. Similarly, Peking University ranks 15th for all indicators except for the UNW-SC, for which it ranks 9th.

The PCW-PC, PCW-AC, and PCW-RC indicators correlate moderately with the other indicators. Fig. 2 shows that the horizontal and vertical axes of the PCW-PC, PCW-AC and PCW-RC have deeper colors and smaller circles. This is also evident in the ranking results. Table 4 shows that the rankings of the top 5 institutions change significantly when Paper citation indicators are included. Using the PCW-PC and PCW-AC, Huazhong University Science & Technology competes with Tsinghua University for the third position. Nanjing University is 20th for most metrics, but is 51st when using the PCW-PC. Harbin Institute of Technology is in the top 20 when using most metrics, but drops to 148th when the Paper citation indicator is included. The rankings are also improved substantially when including the PCW-RC. The University of Hong Kong is ranked 9th, Shanghai Jiao Tong University is third, Hong Kong University of Science & Technology is 17th and Dalian University Technology is ranked 148th versus 18th for most metrics.

Interestingly, the Standardized word weighted indicator is strongly correlated with a paper length weighted counterpart, regardless of the use of the Adjusted count or Real count. This is also evident from Table 4, which indicates that institutional rankings based on the SWW-RC and JPW-RC, and the SWW-AC and JPW-AC are the same. Moreover, the Impact Factor weighted indicator and the journal ranking weighted indicator are highly correlated. Table 4 shows that the IFW-RC and JRW-RC produce the same rankings.

From the perspective of quality-weighted indicators, Journal page weighted, Journal ranking weighted, Standardized word and Impact factor weighted indicators are strongly correlated with their respective counterparts, without quality weighted indicators. It is evident from the rankings of the institutions (Table 4) that each pair, the JPW-AC and UNW-AC, the JPW-RC, and UNW-RC, the JRW-SC and UNW-SC, the JRW-RC and UNW-RC, the SWW-PC and UNW-PC, the SWW-PC and UNW-PC, the SWW-AC and UNW-AC, the SWW-RC and UNW-RC, and the IFW-RC and UNW-RC, result in the same rankings.

As shown in the Table 3, for many of the indicators, the median is equal to or very close to the minimum value, which suggests that the correlation may be influenced by a large number of minimum values. Therefore, it is necessary to verify the robustness of the analysis with different sized datasets. We select the top 100 institutions and top 200 institutions according to the UNW-PC indicator from the full dataset with 1702 institutions. Firstly, we calculate Kendall's τ coefficient value between each pair of indicators for the top 100 institutions and top 200 institutions. Secondly, we compare it with the full dataset. Table 6 shows the Kendall's τ coefficient value between each pair of indicators for the top 100 institutions and top 200 institutions.

We compare the correlations from the top 100 institutes and the top 200 institutes in Table 6 with the correlations from the full dataset in Table 5. There are 17 indicators, and 136 indicator Kendall's τ coefficient value (17*16/2) at a dataset. τ_{t100},τ_{t200},andτ_{full}indicate the τ coefficient values from the top 100 institutes, the top 200 institutes, and the full dataset respectively. For instance,$|\tau_{t100} - \tau_{t200}|$indicates the absolute difference of τ coefficient between from the top 100 institutes and the top 200 institutes. Fig. 3 shows the boxplot of absolute difference from different datasets.

The results show that Kendall's τ coefficient value between the top 200 institutions and the top 100 institutions is closest. The mean of the absolute coefficient difference is 0.025. There is a slight difference of τ coefficient value between the top 200 institutions, the top 100 institutions, and the full dataset. The mean of $|\tau_{t100} - \tau_{full}|$and $|\tau_{t200} - \tau_{full}|$ are 0.212 and 0.188 respectively. Although there is some difference, the results from the full dataset can be treated as a relatively robust result.

5. Results and discussion

In this paper, we conduct an experiment to rank Chinese institutions in the field of Information Management based on 17 bibliometric indicators. Different indicators have different effects on institutional ranking.

Table 6
Kendall's correlations between 17 bibliometric indicators from top 100 institutes and top 200 institutes.

Indicators	UNW-PC	UNW-NC	UNW-SC	UNW-AC	UNW_RC	IFW-PC	IFW-RC	JPW-AC	JPW-RC	PCW-PC	PCW-AC	PCW-RC	JRW-SC	JRW-RC	SWW-PC	SWW-AC	SWW-RC
UNW-PC	1																
UNW-NC	0.97/0.95	1															
UNW-SC	0.79/0.80	0.79/0.81	1														
UNW-AC	0.86/0.87	0.85/0.87	0.82/0.85	1													
UNW_RC	0.83/0.84	0.82/0.85	0.84/0.87	0.93/0.94	1												
IFW-PC	0.90/0.92	0.88/0.90	0.73/0.80	0.82/0.85	0.78/0.83	1											
IFW-RC	0.80/0.81	0.79/0.82	0.80/0.86	0.89/0.89	0.91/0.91	0.81/0.84	1										
JPW-AC	0.86/0.88	0.85/0.89	0.82/0.83	0.94/0.94	0.90/0.90	0.78/0.84	0.84/0.84	1									
JPW-RC	0.83/0.86	0.82/0.86	0.84/0.86	0.89/0.92	0.94/0.93	0.76/0.82	0.86/0.85	0.92/0.94	1								
PCW-PC	0.71/0.72	0.69/0.70	0.61/0.68	0.66/0.71	0.65/0.71	0.70/0.72	0.66/0.70	0.65/0.69	0.64/0.69	1							
PCW-AC	0.70/0.70	0.68/0.69	0.63/0.71	0.70/0.72	0.69/0.73	0.68/0.70	0.69/0.73	0.68/0.69	0.67/0.70	0.90/0.90	1						
PCW-RC	0.70/0.68	0.68/0.68	0.65/0.72	0.70/0.72	0.71/0.73	0.68/0.69	0.71/0.74	0.69/0.69	0.69/0.71	0.87/0.87	0.94/0.95	1					
JRW-SC	0.77/0.77	0.77/0.78	0.95/0.94	0.79/0.82	0.81/0.84	0.73/0.80	0.80/0.86	0.78/0.79	0.80/0.81	0.62/0.69	0.64/0.72	0.66/0.73	1				
JRW-RC	0.82/0.82	0.81/0.82	0.82/0.87	0.89/0.90	0.92/0.92	0.80/0.83	0.93/0.94	0.86/0.86	0.87/0.87	0.68/0.71	0.71/0.74	0.73/0.74	0.83/0.88	1			
SWW-PC	0.94/0.96	0.92/0.92	0.76/0.79	0.81/0.86	0.78/0.83	0.86/0.90	0.76/0.79	0.81/0.87	0.78/0.85	0.70/0.71	0.68/0.70	0.68/0.68	0.75/0.77	0.79/0.82	1		
SWW-AC	0.86/0.86	0.85/0.86	0.81/0.85	0.93/0.94	0.88/0.92	0.81/0.84	0.86/0.88	0.90/0.92	0.86/0.90	0.68/0.71	0.71/0.73	0.72/0.73	0.80/0.84	0.89/0.90	0.84/0.86	1	
SWW-RC	0.83/0.83	0.82/0.84	0.84/0.88	0.89/0.91	0.93/0.95	0.79/0.82	0.89/0.90	0.88/0.89	0.90/0.91	0.67/0.70	0.70/0.73	0.72/0.74	0.83/0.85	0.93/0.93	0.81/0.84	0.92/0.94	1

Note: In the table, the right is the coefficient value of the top 100 institutions and the left one is the coefficient value of the top 200 institutions

Among the article count indicators, Straight count is significantly different from the others. The UNW-SC has weaker correlation coefficients with the UNW-PC, UNW-NC, UNW-AC and UNW-RC (Table 5). Rankings that take the UNW-SC into account are substantially different from those that do not. Importantly, the mathematical properties of the Straight count index, that is, that only the first author of a paper is given credit for a work because it is assumed that every article is equal and the first author is solely responsible for idea creation, excludes contributions of coauthors and co-institutions. However, in modern research, cooperation between institutions and fields is necessary. Cooperation across institutions and nations in the field of Information Management is especially common. For example, Clark et al. found that, recently, coauthoring in the top Information System journals was prevalent (Clark, Au, Walz, & Warren, 2011). Moreover, in some fields, first authorship is used, while in other fields alphabetical order or last author (often the corresponding author) are the norm. The order is often decided by the publication practices of the journal. Therefore, we assert that the use of the Straight count weighted indicator can distort rankings.

Additionally, rankings based on the Real count index do not change substantially when we take into account the quality of the publications. Although each pair of these indicators: the JPW-RC and UNW-RC, the JRW-RC and UNW-RC, the SWW-RC and UNW-RC, and the IFW-RC and UNW-RC, is different. It is unexpected that the correlations between these indicators are so strong. The existence of a trade-off between quality and quantity is supported by our experiment. Wildgaard (2015) compares different indicators and finds that scholars with low numbers of publications and citations are often at the bottom of the rankings. That is, article counts have a strong correlation with other indicators to assess institutional research productivity. This can be explained by the science policy of China and the scientific activities of institutions. For example, Tsinghua University is consistently among the top 5 across metrics. Tsinghua University encourages its researchers and faculty to publish high-quality articles and emphasizes quantitative output as well. Candidates for tenure and promotion, as well as year-end research assessments, should comply with regulations regarding what and how many articles to publish. Such a research policy creates a robust ranking pattern across indicators, whether weighted by quality or quantity of publications.

Another important finding is that the citation weighted indicator is significantly different and greatly changes the pattern of the rankings. The use of citations to assess the scholarship and academic prestige of a paper has limitations (Butler, 2010; Griffith, Cavusgil, & Xu, 2008; Ma et al., 2008). The two big limitations related to citations are as follows. First, there is no quality control regarding citations, such as the citation coming from authors' self-citation. Second, the citation indicator depends on the popularity of the subject matter and the recency of the paper (Mingers & Lipitakis, 2013; Wildgaard, 2015). While several studies incorporate citations in their assessment, they are not perfect. We suggest that researchers pay more attention to new quality-related indicators, such as the rating of a journal. This study showed that the Journal rating indicator provides a robust assessment of institutional research productivity.

6. Limitations to the study

This study, as with all research, has some limitations. First, the reliance of this study on the WoS database to compile quantity- and quality-weighted indicators may be limiting or not inclusive. However, because citation counts and impact factors can be found using the WoS database, it is appropriate for the task.

Second, this paper does not take into account the size of the institutions or number of faculty members. These variables are fundamental to the calculation of institutional productivity (Dridi et al., 2010). However, in the literature, there are few ranking studies adjusted for faculty size because it is difficult to accurately measure faculty size (Mudambi, Peng, & Weng, 2008). However, given that the objective of the paper is to compare and analyze the relationship between indicators, it is a reasonable assessment because all 17 indicators were calculated and compared, despite not adjusting for the institution size and faculty number.

7. Concluding remarks

Academic interest in the ranking of departments stems from the need to evaluate academic output using objective metrics. This paper proposes an indicator framework, which consists of article count indexes and quality weighted indexes, to rank institutional research performance. Based on the literature review, 17 indicators are selected for study using the framework. Experiments are conducted to rank Chinese institutions in the field of Information Management across these indicators. The result shows that, among article count indicators, the Straight count indicator is significantly different from the others. Given the mathematical properties of the Straight count index, we do not suggest using the Straight count index to rank institutions in the field of Information Management or quickly developing subjects or fields. The experiment shows a trade-off between quality and quantity. This can be explained by the science policy of China and the scientific activities of institutions. Additionally, this study finds that the Paper citation weighted indicator is sensitive to the procedure used for institutional ranking. Given the limitations of the citation indicator, we suggest that more broad quality-related indicators should be used to evaluate institutional productivity ranking.

Acknowledgments

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Appendix: The value of the indicator of each journal

Journal Title	5Y IF	JR in ABS	RS	APP	TCP	ACP	TAT
Behaviour Information Technology	1.41	2	1	13	1057	14,108	949
British Journal of Educational Technology	1.68	2	1	10	507	5193	2285
Business Information Systems Engineering	1.86	2	1	12	817	10,053	322
Communications of the ACM	3.61	2	1	8	653	5344	5251
Computer Journal	0.96	2	1	15	816	12,232	1382
Computers in Human Behavior	3.62	3	2	9	1163	10,102	3252
Database: the Journal of Biological Databases and Curation	4.51	2	1	10	766	7660	494
Decision Support Systems	2.93	3	2	11	1202	13,371	1983
Electronic Commerce Research and Applications	2.34	2	1	12	1007	11,921	492
European Journal of Information Systems	2.21	3	2	18	902	16,262	681
Expert Systems	0.94	2	1	12	649	7899	472
Expert Systems with Applications	2.57	3	2	10	1284	13,393	9199
Government Information Quarterly	2.32	3	2	10	1243	12,886	964
Health Information and Libraries Journal	0.63	2	1	9	654	5930	561
Industrial Management Data Systems	1.54	2	1	19	541	10,179	1056
Information Management	3.11	3	2	11	1160	13,050	911
Information and Organization	1.73	3	2	19	744	14,095	109
Information Processing Management	1.27	2	1	15	677	10,117	1186
Information Society	1.05	3	2	12	810	9536	665
Information Systems and E-Business Management	0.81	2	1	24	465	10,974	210
Information Systems Frontiers	1.18	3	2	16	980	15,567	714
Information Systems Journal	1.77	3	2	20	537	10,864	372
Information Systems Management	0.89	2	1	14	852	12,319	653
Information Systems Research	2.44	4*	4	19	824	15,557	569
Information Technology People	0.78	3	2	21	539	11,439	161
Information Technology for Development	0.55	2	1	19	478	8949	177
Interacting with Computers	1.77	2	1	12	916	11,066	704
International Journal of Electronic Commerce	3.09	3	2	29	571	16,469	376
International Journal of Human Computer Studies	1.83	3	2	14	322	4663	1059
International Journal of Information Management	1.55	2	1	10	738	7346	1011
Journal of Computer Information Systems	1.12	2	1	10	1022	10,286	747
Journal of Computer Mediated Communication	3.12	3	2	19	615	11,617	500
Journal of Global Information Management	0.42	2	1	21	449	9405	187
Journal of Global Information Technology Management	0.71	2	1	24	583	14,186	142
Journal of Information Science	1.16	2	1	14	766	10,763	788
Journal of Information Technology	4.53	3	2	16	793	12,952	436
Journal of Management Information Systems	2.06	4	3	31	532	16,240	673
Journal of Strategic Information Systems	2.69	3	2	16	1057	17,246	336
Journal of Systems and Software	1.49	2	1	14	1097	15,858	2404
Journal of the American Society for Information Science and Technology	1.85	3	2	14	850	11,503	2544
Journal of the Association for Information Systems	1.77	4	3	27	392	10,584	338
MIS Quarterly	5.31	4*	4	26	881	23,018	644
MIS Quarterly Executive	1.95	2	1	13	608	7904	153
Requirements Engineering	1.47	2	1	23	907	20,488	238

This table reports the value of main indicators for each journal. 5Y IF= 5-year Impact Factor, JR in ABS= journal ratings in ABS Journal Guide, RS= the rate score, APP= the average total pages per article, TCP= the average total characters per page, ACP= the average total characters per article, TAT= total number of articles from 2001 to 2015.

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