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# Publication delay adjusted impact factor: The effect of publication delay of articles on journal impact factor

Xiaolong Guo*, Xiaoxiao Li, Yugang Yu*

*Anhui Province Key Laboratory of Contemporary Logistics and Supply Chain, School of Management, University of Science and Technology of China, 96 Jinzhai Road, Hefei, 230026, PR China*

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ABSTRACT

The journal impact factor (JIF) has been questioned considerably during its development in the past half-century because of its inconsistency with scholarly reputation evaluations of scientific journals. This paper proposes a publication delay adjusted impact factor (PDAIF) which takes publication delay into consideration to reduce the negative effect on the quality of the impact factor determination. Based on citation data collected from *Journal Citation Reports* and publication delay data extracted from the journals' official websites, the PDAIFs for journals from business-related disciplines are calculated. The results show that PDAIF values are, on average, more than 50% higher than JIF results. Furthermore, journal ranking based on PDAIF shows very high consistency with reputation-based journal rankings. Moreover, based on a case study of journals published by *ELSEVIER* and *INFORMS*, we find that PDAIF will bring a greater impact factor increase for journals with longer publication delay because of reducing that negative influence. Finally, insightful and practical suggestions to shorten the publication delay are provided.



## 1. Introduction

Academic publishing propagates academic works in the form of journal articles, books, and theses. An academic journal article is the most common way to get research progress published and widely known by peer researchers. Seeking to have a broader influence, researchers prefer to publish their work in highly acknowledged and well-known journals. Thus, journal evaluation indexes which can systematically assess the academic impact of journals have been proposed and examined in recent decades. Among these, the journal impact factor, JIF for short, has become the most widely adopted index.

*Journal Citation Reports* (JCR), an annual publication of *Clarivate Analytics*, provides basic information about selected academic journals (e.g., number of citable items, number of citations) and various evaluation indexes including JIF. JIF is defined as the number of citations received in that year, of articles published in that journal during the two preceding years, divided by the total number of articles published in that journal during the two preceding years (Garfield & Sher, 1963). We display this as Eq. (1) in Section 3. A higher JIF for a journal means its articles published in the lastest two years are, on average, cited more often; in other words, journals with higher JIF have greater short-term academic influence.

Citation behavior and the numerical value of JIF, however, vary between different categories, which means the JIF result might not be clear to researchers how a journal behaves in its category if they are not familiar with all journals in the

* Corresponding authors.
*E-mail addresses:* gxl@ustc.edu.cn (X. Guo), lilianli@mail.ustc.edu.cn (X. Li), ygyu@ustc.edu.cn (Y. Yu).

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category. Therefore, journals in JCR are categorized according to research fields and ranked based on JIF in each category. To ease the difficulties in judging the rank of a journal, the JIF Quartile classification criterion is used as well. It classifies journals ranked first, second, third, and fourth quarter among the journals in the same category as "Q1", "Q2", "Q3", and "Q4" journals. This information, together with the journal ranking, is presented to help clarify journals' academic position in its category. Journals ranked in the first quarter (i.e., the Q1 journals) are commonly recognized as top journals in their fields by professionals and researchers. The JIF index with these simple and rough criteria is, unfortunately, widely adopted in university ranking, discipline evaluation, and university performance evaluation by governments.

Expert ranking differs from citation-based indexes. Over years of article reading and publishing, professional scholars formed their individual perspectives on the academic influence of journals in their field. Subsequently, widely accepted and highly respected journals are summarized and organized into a journal list that indicates what scholars rank as the top journals in a specific field. Journals on the list have very good reputations among researchers and are widely taken as field-leading ones. Having an influence similar to the famous JIF, these journal lists are also widely used in evaluating the research performance of researchers, institutions, and universities. For example, the NATURE INDEX[1] is a database concerned with 82 top journals in Chemistry, Earth & Environmental Science, Life Science, and Physical Science, showing the number of articles published by universities, research institutes, and countries in these research journals (https://www.natureindex.com/faq#journals). The "UTD 24" journal list published by *The University of Texas at Dallas*, as another example, is a summary of top journals, playing a similar role in the business and management field. This journal list is used to evaluate the research performance of researchers and institutions in finance, accounting, management, and other business-related disciplines (https://jindal.utdallas.edu/the-utd-top-100-business-school-research-rankings/).

JIF and top journal lists both try to evaluate journal academic influence and inform researchers about top academic journals, but with different methods and from different perspectives. However, mismatches always exist between the citation-based JIF and reputation-based professional top journal lists. To be specific, many journals listed high in the professional journal list have low impact factors, and thus, are listed as Q3 or Q4 journals in JCR. The rapid development of JIF has always been accompanied by criticism because of these mismatches. Both journal editors and researchers have long been calling for revision or replacement of JIF (Alberts, 2013; Casadevall et al., 2016; Shi, Rousseau, Yang, & Li, 2017).

In the JCR category, *OPERATIONS RESEARCH & MANAGEMENT SCIENCE* (OR&MS, a field in the JCR category list), exemplifies the situation that journals with very high reputations do not gain good JIF and category rankings (details are in Section 5). Journals such as *OPERATIONS RESEARCH*, *MANUFACTURING & SERVICE OPERATIONS MANAGEMENT*, *PRODUCTION AND OPERATIONS MANAGEMENT*, and *INFORMS JOURNAL ON COMPUTING*, which are all top journals in the field and are listed in the UTD 24 journal list, ranked 25th, 34th, 35th, and 47th of 84 journals in the 2017 JCR ranking. This implies that all of them are ranked out of the Q1 quartile in their field. This situation confuses young scholars, who have insufficient experience in this field, when they choose target journals for their articles; they may unintentionally publish in actual top journals with lower JIF or statistically top journals that have a lower academic reputation. Despite the fact that one of the incentives for designing JIF is to provide guidance for researchers who are submitting articles (Garfield, 2006), it produces misleading evaluation results and causes many problems for academic journals, institutions, universities, and governments, as well as individual researchers.

Previous research revealed that publication delay, which is the time gap between article submission and publication (Shi et al., 2017), negatively influences JIF's accuracy. Because of the definition and calculation process of JIF, this delay invalidates citations and enlarges the manipulation behavior of JIF, as citations that would otherwise be valid are pushed out of JIF's 2-year valid period and brings in the effect of "*strategic citations*" (citations added during the review process to satisfy the review team). Moreover, if the publication delay is longer than two years, the 2-year validity period for calculating JIF will be fully covered by the review process, and none of the original citations will be valid (Shi et al., 2017). To fix this problem, in this paper, we investigate the influences brought by publication delay and propose a revised method.

Our study concentrates on the negative effect of publication delay on JIF. We model the citing process between journals and explain how the publication delay influences the calculation of JIF, confirming that publication delay has a significant negative influence on the accuracy of the JIF evaluation result. We demonstrate the worst case of a two-year publication delay, which leads to the situation that none of the citations in the first draft are valid in the calculation of JIF. Meanwhile, strategic citations added during the review process are valid for calculating JIF, even though they do not contribute to generating the research idea (which is the core of research innovation). This means that impact factors in this situation are calculated based totally on citations added during the review process, and so JIF cannot evaluate the academic influence of journals precisely.

To identify the influence of publication delay on JIF and deliver practical suggestions, we propose a revised model that considers publication delay. The model is validated by citation data collected from the JCR website and publication history data collected from the journals' official websites. According to this revised model, the publication delay adjusted impact factor (PDAIF) is defined, based on which the academic publication situations for journals are analyzed. Our results show that PDAIF gives reputation-based top journals a much better ranking, placing most of them in the Q1 quartile. In particular, a case study comparing *INFORMS* Publishing and *ELSEVIER* is performed to reveal implications and suggestions.

[1] https://www.nature.com/articles/d41586-018-05559-2.

The remainder of the paper is organized as follows. Section 2 introduces previous relevant research, and is followed by Section 3, in which a model for the review and citation process and a new JIF revision equation are proposed. Section 4 introduces the data used in this research. Section 5 reports the JIF ranking results for two top journal lists and shows the real publication delay as well as the PDAIF numerical and ranking results. Based on the results, Section 6 presents a case study comparing two major publishers, *ELSEVIER* and *INFORMS*, to uncover implications and suggestions. Finally, Section 7 concludes the paper with a summary and future research directions.

## 2. Literature review

First introduced by Garfield and Sher (1963), JIF has been highly adopted, yet questioned in its widespread usage over the past half-century. Designed as a tool to select journals for the *Science Citation Index*, it is now used to evaluate not only journals, but also the academic achievements of scholars, researchers, research institutions, and even countries (Casadevall & Fang, 2014). However, many researchers and journal editors doubt the accuracy of its results (Amin & Mabe, 2000), and aim to standardize its usage, or find more accurate revisions of it, or simply abandon this kind of evaluation index (Amin & Mabe, 2000; Casadevall et al., 2016; Moed & Van Leeuwen, 1995). Researchers have found many reasons explaining its inaccuracy in evaluating academic publishing-related entities (Casadevall & Fang, 2014), among which publication delay is prominent as a negative influence on JIF accuracy (Shi et al., 2017).

Currently, JIF is used to evaluate the quality of journals as well as research articles, researchers, and other research entities. Garfield (2006) described JIF as a measurement of journal's academic performance and a tool helping libraries decide which journals to purchase. What is more, journals may gain high prestige by having a relatively high JIF, which will influence researchers submitting articles. As a result, the individual article and its author(s), according to Shi et al. (2017) and Tort, Targino, and Amaral (2012), are also evaluated by the JIF of the journal where the article is published. Researches have revealed that the impact of JIF has spread to researchers' promotion, research funding application, research institution ranking, and similar evaluation activities (Alberts, 2013; Anonymous, 2002; Casadevall & Fang, 2014; Moed & Van Leeuwen, 1995; Seglen, 1997). A more recent study with large data Zhang, Rousseau, and Sivertsen (2017) also emphasized that the JIF of a journal is not positively related to the academic contribution of the articles it publishes. Frandsen and Rousseau (2005) proposed a class of article evaluation indicators defined using formulas similar to but more general than JIF.

Although JIF is widely used and of great academic influence, it has received many criticisms about its appropriateness as an evaluation index. Simons (2008), Casadevall and Fang (2014), and Alberts (2013) all pointed out the misuse of JIF for evaluating academic research, researchers, and other academic entities, and emphasized that this judgment should be made by peer researchers. Also, Seeber, Cattaneo, Meoli, and Malighetti (2019) revealed the misbehavior of researchers when this kind of metric is taken as a standard for promotion decisions. Faced with this problem, a group of editors and publishers of cell biology journals gathered together for discussion and announced *The San Francisco Declaration on Research Assessment*, emphasizing the problem and providing suggestions (Cagan, 2013). Furthermore, as a tool to evaluate academic journals, the accuracy of JIF has long been doubted. Amin and Mabe (2000) indicated that the value of JIF is influenced by the subject, type, publishing environment, and other factors of the journal. For example, review articles are more likely to be cited than original research articles (Simons, 2008). The inappropriate definition of "citable item" and the time difference between articles being published online and in-print both bias JIF results, according to Moed and Van Leeuwen (1995) and Tort et al. (2012). Vanclay (2009) pointed out the misleading indication of the true impact of journals by discussing the unfairness of the JIF two-year window to journals in different fields, and as a result, concluded that JIF could not provide a comparable evaluation across different fields. Garfield (2006) also admitted that publication delay invalidates citations and makes JIF lose accuracy. Further, Dong, Loh, and Mondry (2005) summarized the factors that bias the calculation of JIF. Wilhite, A. Fong, and Wilhite (2019) proved with real data that journal editors may actively manipulate JIF with various methods, and that journals in the same (or an interconnected) field tend to share the same JIF influencing behavior, bringing more evaluation bias into the research community.

To solve the problems mentioned above, numerous revisions of JIF have been proposed (Dong et al., 2005; Kumar, 2010). To solve the bias brought by inappropriate definitions of "citable item", the relative distribution of research articles, different citing behaviors, and the fixed two-year window, the *Journal to Field Impact Score* was proposed based on a flexible and selected citation and publication window (van Leeuwen & Moed, 2002). In addition, the *Disciplinary Impact Factor* and *Rank Normalized Impact Factor* were designed to solve the subject bias among different research fields (Hirst, 1978; Pudovkin & Garfield, 2004). Gradually, some revisions have been adopted and included in the JCR report, such as the 5-year IF and JIF without journal self-citations. The former revision focuses on the bias due to the time window, and the latter removes the influence of citations of other papers in the same journal. Moreover, to avoid the misconduct of researchers in promotion evaluation, Maux, Necker, and Rocaboy (2019) developed a principal-agent framework. However, the application of these ideas shows that these revisions still cannot fix the above-mentioned problems (Alguliyev & Aliguliyev, 2016).

Publication delay, defined as the time gap between article submission and its publication (online or in print), significantly influences JIF. As the inventor of JIF, Garfield (2006) indicated that "*If manuscript refereeing or processing is delayed, references to articles that are no longer within the JCR's 2-year impact window will not be counted.*" Through analyzing the publication delay information collected from 2700 articles published in 135 journals, Björk and Solomon (2013) found that the average publication delay differs depending on journal fields, journal sizes, and other factors. These unbalanced publication delays will, in turn, lead to uneven bias in JIF evaluation results in the light of Garfield (2006). Shi et al. (2017) also proved the

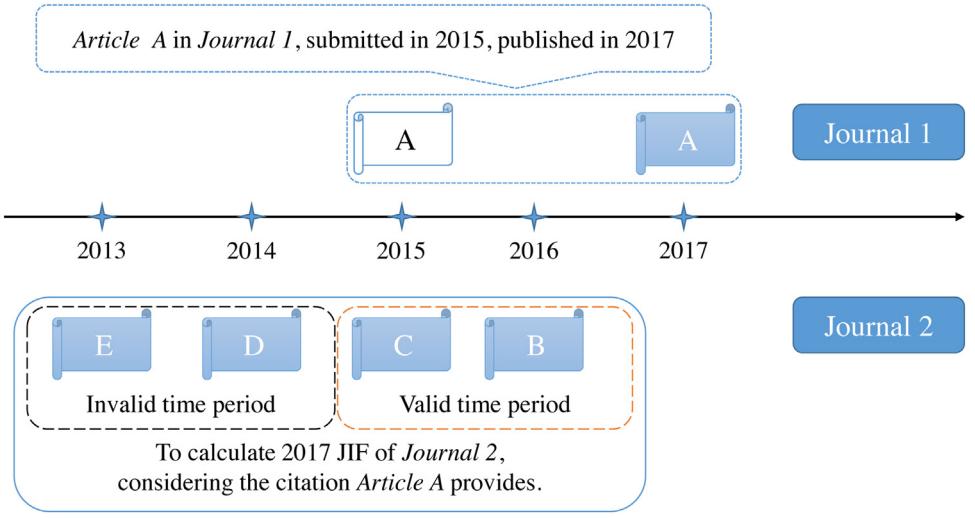



**Fig. 1.** Publication delay influence model.

relationship between one journal's JIF and other journals' publication delays, and their proposed theoretical model showed a monotonically decreasing relationship between them.

Despite how significantly JIF is influenced by publication delay, which varies greatly among different categories, none of the existing revised-JIF methods take publication delay into account. This paper seeks to solve this problem. Investigating the precise impact of publication delay, we demonstrate the inaccuracy of JIF with both a theoretical model and data analysis. Considering publication delay as a factor leading to the inaccuracy of JIF, we model the citation process and explain the origin of the negative influence delay brings from the definition of JIF. Instead of using interview data with strong subjectivity or a purely theoretical model, we use JCR data and the public information provided on the journals' official websites. These data confirm the negative influence of publication delay and the existence of mismatches between JIF-based top journal lists (i.e., Q1 journal list) and the peer-approved top journal lists (such as "UTD 24 Journal List" for business and management and "NATURE INDEX" journal list for basic natural science). To improve the situation, a new JIF variant based on publication delay is proposed. The results calculated based on real citation data show that the new JIF-based top journal list results have high correspondence with peer-approved (reputation-based) top journal lists.

## 3. Model description

Following the definition applied in *Journal Citation Report*, the JIF for a journal of year $y$ is calculated as:

$$IF_y = \frac{Citations_{y-1} + Citations_{y-2}}{Publication_{y-1} + Publication_{y-2}}, \tag{1}$$

where $Publication_{y-1}$ is the number of citable items published in year $(y-1)$ of the journal, and $Citations_{y-1}$ is the number of citations in year $y$ to items published in year $(y-1)$. $Publication_{y-2}$ and $Citations_{y-2}$ are defined similarly. Since JIF is calculated based on the data of the most recent two years, it is also known as the *2-year Impact Factor*.

To better characterize the model, without loss of generality, consider a cross-citation model consisting of two journals with only a single citation. As Fig. 1 shows, *Article A* is published in *Journal 1* in 2017 and cites one of *Articles B*, *C*, *D*, and *E*, which are published in *Journal 2* in 2016, 2015, 2014, and 2013, respectively. Following Eq. (1), *Article A* will contribute to *Journal 2*'s 2017 JIF if it cites *Article B* or *Article C*; while citations of *Article D* or *Article E* will not influence the 2017 JIF of *Journal 2*.

To see the influence of publication delay on JIF, we further assume that the publication delay of *Journal 1* is two years. According to the definition of JIF and the analysis of Garfield (2006), a 2-year publication delay will lead to the worst-case scenario, that none of the citations of the first draft of *Journal 1* are valid for the JIF of 2017, the year the article is actually published. In this setting, the author(s) of *Article A* submitted their paper in 2015 and performed the research before 2015, and it is impossible for them to refer to the ideas of *Article B* and *Article C* which are published after its submission. Nevertheless, these two articles can still be cited when *Article A* is published, that is, during the revision process of *Article A*. Consequently, *Articles D* and *E* may contribute by generating innovative ideas for *Article A*, but they are invalid for JIF when the citing paper is published. In contrast, *Articles B* and *C* made no contribution to generating innovative ideas for the focal paper, yet they may contribute to the journal's impact factor. As a result, the publication delay negatively influences JIF accuracy through citations.

The quantity of citation decreases because publication delay pushes citations that should have been effective out of the JIF's window of validity. The longer the publication delay is, the fewer valid citations there will be. In the worst case of a two-year publication delay, none of the citations in the originally submitted paper will be valid. As a result, with the growth of publication delay, JIF depends more and more on citations added during the review process, the so-called "Strategic Citations". Such citations, as existing literature has found, are added by the author(s) (usually because of suggestions from editors or referees) to please target journals or potential reviewers to increase the likelihood of the paper being accepted (Wren, Valencia, & Kelso, 2019). However, this type of citation contributes little to the original research and so reflects nothing about the academic influence of both the cited articles and the journal, and as a result, leads to inaccurate evaluation results of JIF.

Furthermore, according to sampled citation data of journals from JCR, almost 50% of the citations a journal receives are from journals in the same category, and the second-highest citing category accounts for less than 10%. This tells us about the importance of the research environment, and to what extent it will influence the JIF of journals in the category. Previous research has also shown that the publication delays of journals in the same category are similar (Björk & Solomon, 2013), and this conclusion is also supported by our data collected in this research. Furthermore, this aligns with intuition, considering the coincidence of reviewers and similar review processes for journals in the same category. Taking these two situations into consideration, we believe that a category-based impact factor revision will improve its accuracy and help build a healthier academic community for each individual category.

Based on the above discussion, a "Publication Delay Adjusted Impact Factor" (PDAIF) is proposed to avoid the negative influence brought by publication delay. Assuming the average publication delay of the category is $x$ (years), the PDAIF for a journal of year $y$ is given as the following Eq. (2):

$$PDAIF_y = \frac{Citations_{y-1-x} + Citations_{y-2-x}}{Publication_{y-1-x} + Publication_{y-2-x}}. \tag{2}$$

Based on this definition, the PDAIF can both make valid those citations that are pushed out of JIF's original 2-year window and exclude the citations added during the review period.

Recall the example shown in Fig. 1. In this circumstance, a citation of *Articles* $D$ or $E$ will contribute to the 2017 PDAIF of *Journal* 2, but any citation of *Articles* $B$ and $C$ will be invalidated. Compared to JIF, this practice moves the period of validity back to the time during which the idea of the article was generated and developed. This brings back valid citations while leaving out "Strategic Citations" added during the review process, thus resulting in a more accurate academic evaluation result.

To illustrate the effectiveness of the proposed PDAIF, we assess the influence of publication delay using data collected from JCR and some journals' official websites in the following part. Section 4 presents a description of the collected data, and Section 5 gives the results.

## 4. Data collection

In this paper, we use datasets from two sources. (1) JCR website: Here, we get the categorized journal ranking lists with journal information, detailed citation information (such as the number of citations, self-citations, number of citable items) as well as journal impact factors (2-year and 5-year JIF). These data illustrate the calculating process of JIF and 5-year JIF, together with the JIF ranking result. (2) Journals' official websites: From these, we collect the publication history data for each article. Because of the huge number of journals and articles, journals from only the two top journal lists are selected as samples to represent the whole data. The first one is NATURE INDEX, which contains 82 top journals in the disciplines of Chemistry, Earth & Environmental Science, Life Science, and Physical Science; the second one is the UTD 24 journal list which contains 24 elite journals in finance, accounting, management, and other business-related disciplines.

### 4.1. JCR data

JCR provides comprehensive data about SCI journals, based on an annual categorized journal ranking list according to JIF combined with other journal-related information. This data is provided to help researchers better understand the performance of each journal from a statistical point of view. In this paper, we collect the categorized journal JIF ranking data and citation data together with citable item information data that is used to calculate journal 5-year impact factors. The following data were collected from JCR:

2 We downloaded all the journal category lists from 2013 to 2017 with all provided journal information, including journal JIF ranking, journal full and abbreviated names, and journal unique identifier "ISSN". It should be noted that, as shown in Table 1[2], JCR has a varying number of categories, and each category may have a varying number of journals from year to year. Categories or journals may arise or disappear due to multiple reasons, so to maintain consistency in our comparison,

[2] Multi-disciplinary journals are classified into more than one category. Hence, in Table 1, "Journals" represents the exact total number of journals appearing in JCR, and "Journal occurrences" represents the total number of journals in all categories without subtracting the repeated journals.

**Table 1**
Summary statistics of JCR data over the years 2013–2017.

| No. | 2017 | 2016 | 2015 | 2014 | 2013 |
|---|---|---|---|---|---|
| Categories | 235 | 234 | 234 | 232 | 232 |
| Journals | 12,298 | 12,090 | 11,997 | 11,770 | 11,570 |
| Journal occurrences | 18,814 | 18,503 | 18,331 | 17,952 | 17,638 |

we take the 2017 journal lists as a standard for further PDAIF related analysis. To avoid too much difference in the category lists, we only collected JCR information in the five consecutive years 2013–2017. Commonly, one journal could be classified into multiple categories, since the journal may be interdisciplinary and publish articles from different fields. In this case, we will take the highest-ranking percentage result of that journal during this study.

3 The citation information used to calculate 5-year impact factors cannot be downloaded directly, so it was collected with web-scraping tools. We collected this information of 619 journals from five business-related categories (in line with the UTD 24 journal list) for the most recent five years, and use category lists in 2017 as standard categories. Using a definition similar to JIF, the 5-year impact factor uses the number of citations and citable items of the preceding five years. As a result, this citation information can cover that of JIF and PDAIF (with $x$ less than four according to the example shown in Fig. 1). This dataset is used to calculate the PDAIF for journals in these five business-related categories and evaluate the accuracy of PDAIF.

4 From the 2017 JCR report, detailed citation lists of 195 randomly sampled journals (about 1% of JCR journals) and 84 journals from the OR&MS category were downloaded from the JCR website. The 2017 detailed citation list of a journal records all of the citations it received in 2017 to papers it published in 2015 & 2016. Detailed information about the citing papers, including title, publishing journal, and journal ISSN, are all provided. This dataset is used to analyze the citation behavior among categories.

### *4.2. Top journal lists and publication history data*

As presented in previous sections, the NATURE INDEX list and UTD 24 journal list are selected to represent the reputation-based professional top journal lists in this study. The publication history data includes information about important time points in the review process, such as when the journal received the manuscript, accepted the manuscript, and published the article. We collected publication history data for each published article from the journals' official websites using web-scraping tools.

The NATURE INDEX list matches JCR's Q1 list well, and from sample data, we find out that the average publication delay of NATURE INDEX is less than 180 days (6 months). We, therefore, mainly focus on the publication history data for the UTD 24 journals in this study. Among these 24 journals, 10 of them do not provide such information, and thus, a total of 13,454 publication history records from 14 journals were collected, covering papers from 2000 to 2017. The publication history information provided varies between publishers, so, for better comparison, we use two time points, "Received" and "Published Online", that are universally available and can best reflect the length of publication delay. Our sources have various names for these time points, but we use a unified naming convention. It should be noted that the collected data contained two cases in which a journal reprinted a recognized article which had already been published in previous issues: one in *Management Science* (Issue 12_supplement of Volume 50) and the other in *Marketing Science* (Issue 1 of Volume 27). The publication details contained in these two issues are inaccurate, so we cleaned out the information of those repeat articles when we performed our research.

"Received" represents the date that the journal received the manuscript, starting the whole review process. "Published Online" specifies when the article was published and available on the Internet. These two time points describe the time window from the submission of an article to the final digital online publication, and the time gap between them is the publication delay that the paper experiences. One may argue that the period from "Published Online" to "Publish in Print" is also of interest and should influence JIF because the printed journal issues are much later than the digital version of the article. We note that according to a new practice used by *Web of Science* (*WOS*), once a paper is published online, then the paper can be included in *WOS* and is searchable and citable by researchers. Thus, in this paper, we define the publication delay as the time gap between "Received" and "Published Online". Further, we also need to clarify that although a paper with the status "Early Access" is available online for readers, the period from "Early Access" to "Published Online" is included in the publication delay since it cannot be included in *WOS* unless it is "Published Online" with formatting and proofreading.

## 5. Analysis

The JCR ranking list represents the statistical influence of journals, while reputation-based professional top journal lists represent the peer-academic influence of journals. Scholars expect a high degree of agreement between these two types of lists. Thus, in the following Section 5.1, we first investigate the consistency between JCR ranking and top journal lists.

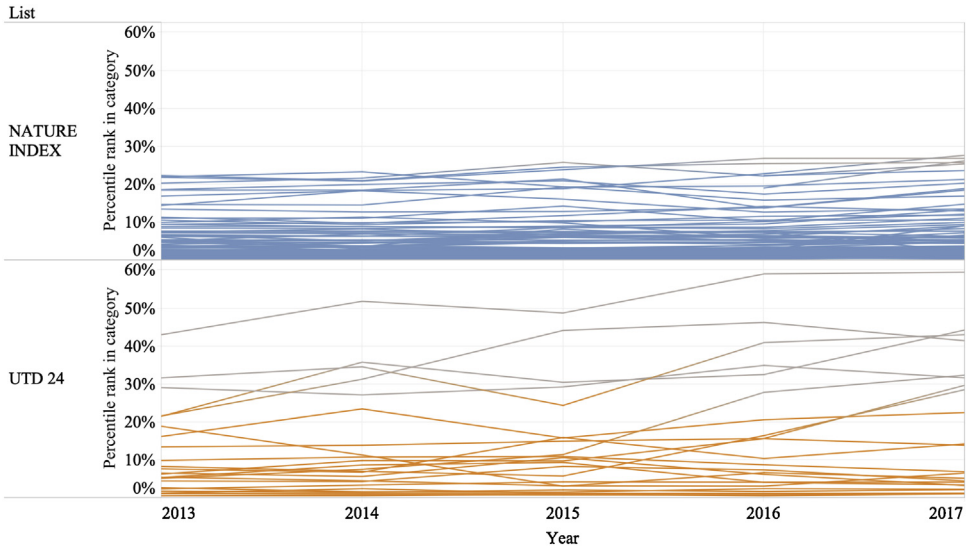



**Fig. 2.** JIF rank of journals on NATURE INDEX and UTD 24 lists.

### 5.1. Mismatch between JCR ranking & top journal lists

As a dominant evaluation index for academic journals, JIF's results and its rankings for journals on the top journal lists reflect the index's evaluation performance. Thus, we take journals from NATURE INDEX and UTD 24 top journal lists as representative of top journals, retrieve their JCR ranking percentage in a category using "ISSN" as a unique ID, and draw the trends over years. If a journal belongs to multiple categories in JCR, we compare the different category ranking percentages and keep the highest one.

The journal ranking percentage trends of NATURE INDEX and UTD 24 journals from 2013 to 2017 are shown in Fig. 2. As we can see, the ranking percentage of NATURE INDEX journals is quite stable, and about 95% journals stay within the Q1 range (journals ranked within the first quartile of the category and defined as top journals by JCR), and all five journals that fall out of the Q1 region ranged very close to the first quartile threshold with the lowest one being 27.8% in its category. More specifically, most listed journals are ranked within the first 10% in the JCR ranking. This result implies that there is a good match between the JIF evaluation and peer-academic evaluation for NATURE INDEX journals.

However, the result for UTD 24 journals is poor: more than 30% of these journals ranked out of Q1, and some of them are ranked at the 40% to 50% level within their categories regarding the 2017 data. What is more, more than half of the listed elite journals are ranked out of the first 10%. This result shows a considerable mismatch between JIF evaluation and peer-academic evaluation for these journals.

As discussed in Section 3, publication delay may be the cause of this mismatch. According to the statistical results of Björk and Solomon (2013), the average publication delay of fields covered by NATURE INDEX is about ten months, but for the *Business and Economics* category, to which the UTD 24 journals belong, the publication delay is more than 18 months. Thus, we are interested in investigating the influence of publication delay on JIF. The following Section 5.2 shows the publication delay information for journals on the UTD 24 list based on data collected from their published articles.

### 5.2. Publication delay of journals on UTD 24 list

In this section, we use publication data collected from published articles of UTD 24 journals to confirm the existence of extremely long publication delays. Among the 24 journals, only 14 of them provide sufficient information for the peer-review process; the other ten journals do not provide publication information or do not have enough records to be considered as a valid sample. The average publication delay for each journal is calculated based on the annual data, and Fig. 3 presents the result for the 14 journals, showing a detailed description of publication delay from 2000 to 2017. As we can see, the *Journal of Operations Management* has the shortest delay and is the only journal with a publication delay shorter than 18 months since 2007, although its delay is still longer than one year. All the other journals have an average publication delay of more than 18 months. Worse still, four of them have a publication delay longer than 1000 days, which implies the delay is approaching and even longer than three years. Based on the information gathered, the average delay for articles published in these journals is 781 days (2.14 years), which is longer than the valid time window length for JCR's JIF com-

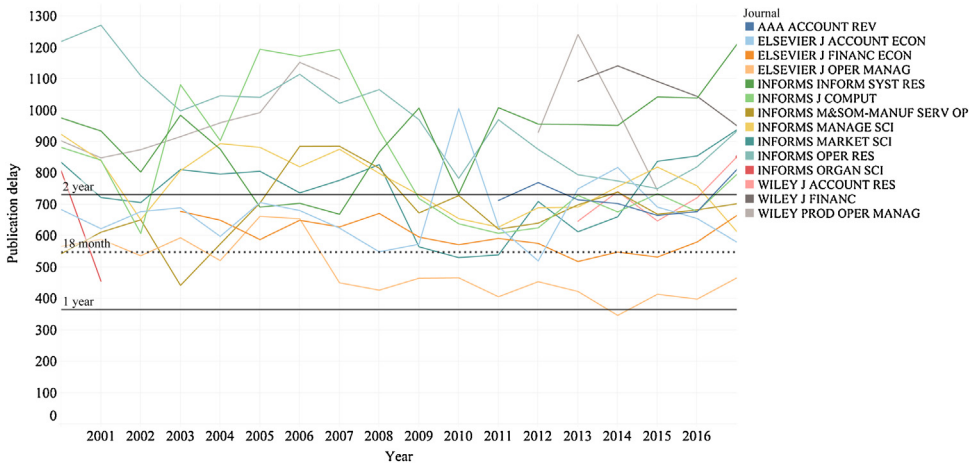



**Fig. 3.** Publication delay information for journals on the UTD 24 list. *Note*: Ten journals that do not provide or do not have enough publication history records are not included.

putation (2 years). For comparison, we sample and calculate the publication delay of four categories covered in NATURE INDEX.[3]

A noteworthy issue is that the average publication delay of journals on the UTD 24 list is much longer than the findings in Björk and Solomon (2013). The discrepancy may be caused by (i) top journals having a longer publication delay than average-level journals due to more rigorous reviews; or (ii) the research methodology: we are performing the research based on all the available information from all articles published from 2000 to 2017, while Björk and Solomon (2013) performed their research based on a sample group of articles (20 per journal on average).

Considering this considerable length of delay in publishing in journals in the business and management field and its effect on JIF (Shi et al., 2017), the metrics adopted by JCR will bring inaccuracy in academic evaluation. This inaccuracy is also explained by our theoretical model given in Section 3, and it is urgent to find a suitable tool to fix this problem. In the next subsection, we will first prove the rationality of our proposed "Publication Delay Adjusted Impact Factor" based on the citation behavior among categories. We then verify its accuracy for the five categories covered by the UTD 24 journal list (namely "BUSINESS", "BUSINESS FINANCE", "MANAGEMENT", "OPERATIONS RESEARCH & MANAGEMENT SCIENCE", and "INFORMATION SCIENCE & LIBRARY SCIENCE").

### 5.3. Publication delay adjusted impact factor

Recall our definition of PDAIF, using which the impact factor for a journal is calculated while taking publication delay into consideration. It should be noted that this publication delay is not for the journal itself, but for the journals which publish articles citing this journal. Hence, it is important to justify the rationality of adopting the average publication delay when calculating the PDAIF. Based on the detailed citation lists of 195 randomly sampled journals from the 2017 JCR report, we first investigate the citation behavior of articles among categories. As Fig. 4 shows, almost 50% of citations are received from journals in the same category, and the second-highest citing category contributes less than 10%. This result tells that using the average publication delay of its category to calculate a journal's PDAIF is reasonable. Furthermore, using this average value will eliminate the influence of a particular journal's publication delay variation.

According to the 2017 JCR report, the 24 journals on the UTD 24 list belong to five JCR categories, namely, *OPERATIONS RESEARCH & MANAGEMENT SCIENCE* with 84 journals, *BUSINESS* with 140 journals, *BUSINESS FINANCE* with 98 journals, *MANAGEMENT* with 210 journals, and *INFORMATION SCIENCE & LIBRARY SCIENCE* with 88 journals. As we can see, the UTD 24 list itself provides a good cluster sample for the representation of these five categories. Therefore, it is reasonable to use the average publication delay of these 24 journals to calculate the PDAIF of journals in the above five categories.

[3] We randomly selected 16 journals (two of them lacked sufficient information) and collected information for the last five years (2015–2019). For each year, we sampled one issue (for journals with at most ten issues per year) or two issues (for journals with more than ten issues per year), and five papers per issue randomly. There may be some articles that have no review time and some issues that have less than five articles. Comments and editorial articles are excluded, and the calculated publication delay was shorter than six months for all four categories.

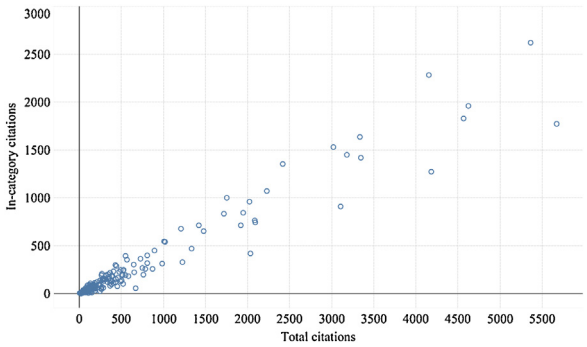
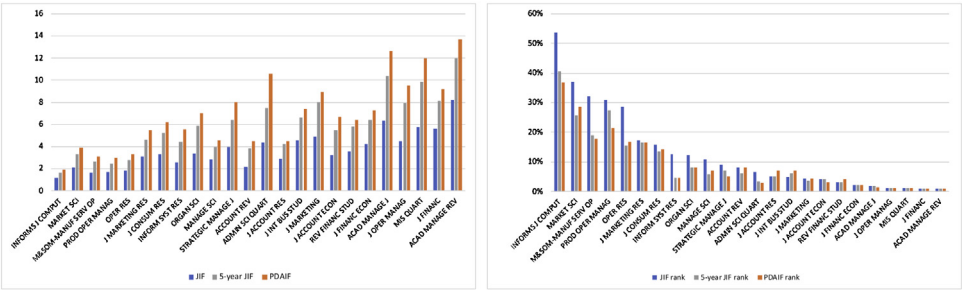



**Fig. 4.** In-category citations of sampled journals. *Note*: Four sampled journals with total number of citations more than 10,000 are removed.

**Table 2**
Average and increase of journal impact factors (from 2007 to 2017).

| Category | Average JIF | Average PDAIF | Increase | Increase percent |
|---|---|---|---|---|
| BUSINESS | 2.05 | 3.55 | 1.50 | 73.17% |
| BUSINESS FINANCE | 1.30 | 2.20 | 0.90 | 69.23% |
| MANAGEMENT | 1.91 | 3.36 | 1.45 | 75.92% |
| OR&MS[a] | 1.39 | 2.06 | 0.67 | 48.20% |
| IS&LS[b] | 1.21 | 1.87 | 0.66 | 54.55% |
| Journals on the UTD 24 list | 3.43 | 6.55 | 3.12 | 90.96% |

[a] "OR&MS" abbreviates "OPERATIONS RESEARCH & MANAGEMENT SCIENCE".
[b] "IS&LS" abbreviates "INFORMATION SCIENCE & LIBRARY SCIENCE".




(a) JIF, 5-year JIF, and PDAIF comparison (b) JIF, 5-year JIF, and PDAIF ranking percentage comparison

**Fig. 5.** Comparison of the 2013–2017-average JIF, 5-year JIF, and PDAIF. *Note*: Journals are sorted based on their JCR ranking percentage in 2017.

According to Eq. (2), the PDAIF for journals on the UTD 24 list is calculated with the publication delay $x = 2$ years based on the analysis of Section 5.2, which is close to the average publication delay of these journals. Therefore, the PDAIF for a journal in year $y$ can be obtained as:

$$PDAIF_y = \frac{Citations_{y-3} + Citations_{y-4}}{Publication_{y-3} + Publication_{y-4}}. \tag{3}$$

The numbers of citable items ($Publication_{y-3}, Publication_{y-4}$) and the numbers of received citations ($Citations_{y-3}, Citations_{y-4}$) can be extracted from the JCR data, which provides detailed citation information when calculating its 5-year impact factor.

PDAIF for all journals in the above five categories are calculated according to Eq. (3) from 2013 to 2017. Compared with JIF values provided by JCR, PDAIF increases the numeric value for almost all journals. The average increases based on the results from 2013 to 2017 are given in Table 2. As we can see, the average increase is more than 50% for four of the five categories, and the least increase (OR&MS category) is 48.20%, which is also close to 50%. More specifically, the average PDAIF for journals on the UTD 24 list is almost doubled, exhibiting a more than 90% increment compared to JCR's JIF.

PDAIF is designed to remove the effect of strategic citations during the review process and enable the influence of citations to the inspiring articles published up to two years before the submission of the citing paper. Our results show that PDAIF can indeed increase the numeric value for journals. Next, we will check the accuracy of PDAIF ranking with respect to the reputation-based top journal list.

**Table 3**
JIF & PDAIF ranking results for journals on the UTD 24 list.

| Journal | Type | 2017 | | 2016 | | 2015 | | 2014 | | 2013 | | 5-year avg. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | IF | Rank | IF | Rank | IF | Rank | IF | Rank | IF | Rank | IF | Rank[a] |
| J OPER MANAG | JIF | 4.899 | 1 | 5.207 | 1 | 4.000 | 1 | 3.818 | 2 | 4.478 | 1 | 4.480 | 1/84 |
| | PDAIF | 8.797 | 1 | 8.597 | 1 | 9.367 | 1 | 10.289 | 1 | 10.544 | 1 | 9.519 | 1/84 |
| MANAGE SCI | JIF | 3.544 | 11 | 2.822 | 13 | 2.741 | 8 | 2.482 | 8 | 2.524 | 5 | 2.823 | 9/84 |
| | PDAIF | 5.726 | 5 | 4.843 | 7 | 4.451 | 6 | 4.029 | 5 | 3.626 | 6 | 4.535 | 6/84 |
| OPER RES | JIF | 2.263 | 25 | 1.779 | 29 | 1.777 | 24 | 1.743 | 22 | 1.500 | 23 | 1.812 | 24/84 |
| | PDAIF | 3.484 | 20 | 3.307 | 16 | 3.054 | 13 | 3.325 | 11 | 3.176 | 11 | 3.269 | 14/84 |
| M&SOM-MANUF SERV OP | JIF | 1.795 | 34 | 1.683 | 34 | 1.966 | 20 | 1.462 | 28 | 1.450 | 25 | 1.671 | 27/84 |
| | PDAIF | 3.352 | 24 | 3.065 | 18 | 3.325 | 11 | 3.096 | 15 | 2.775 | 16 | 3.123 | 15/84 |
| PROD OPER MANAG | JIF | 1.772 | 35 | 1.850 | 27 | 1.732 | 25 | 1.439 | 29 | 1.759 | 17 | 1.710 | 26/84 |
| | PDAIF | 3.598 | 19 | 2.984 | 21 | 2.910 | 15 | 2.631 | 20 | 2.774 | 17 | 2.979 | 18/84 |
| INFORMS J COMPUT | JIF | 1.392 | 47 | 1.173 | 49 | 1.246 | 40 | 1.077 | 42 | 1.120 | 34 | 1.202 | 45/84 |
| | PDAIF | 1.958 | 38 | 2.077 | 32 | 1.576 | 40 | 1.902 | 29 | 2.087 | 23 | 1.920 | 31/84 |
| J MARKETING | JIF | 7.338 | 5 | 5.318 | 9 | 3.885 | 10 | 3.938 | 5 | 3.819 | 5 | 4.860 | 6/140 |
| | PDAIF | 9.094 | 12 | 10.042 | 8 | 8.219 | 5 | 8.085 | 7 | 9.120 | 4 | 8.912 | 6/140 |
| J CONSUM RES | JIF | 3.535 | 33 | 3.800 | 19 | 3.187 | 18 | 3.125 | 16 | 2.783 | 15 | 3.286 | 22/140 |
| | PDAIF | 7.108 | 23 | 6.056 | 22 | 5.038 | 24 | 6.868 | 13 | 5.872 | 13 | 6.189 | 20/140 |
| J MARKETING RES | JIF | 3.854 | 25 | 3.654 | 25 | 3.109 | 19 | 2.256 | 27 | 2.660 | 18 | 3.107 | 24/140 |
| | PDAIF | 7.535 | 21 | 6.017 | 23 | 4.988 | 25 | 4.381 | 20 | 4.411 | 19 | 5.466 | 23/140 |
| MARKET SCI | JIF | 2.794 | 46 | 2.163 | 56 | 1.647 | 53 | 1.860 | 36 | 2.208 | 24 | 2.134 | 52/140 |
| | PDAIF | 3.784 | 57 | 4.336 | 44 | 3.683 | 40 | 3.784 | 28 | 3.820 | 23 | 3.882 | 40/140 |
| J FINANC | JIF | 5.397 | 1 | 6.043 | 1 | 5.290 | 1 | 5.424 | 1 | 6.033 | 1 | 5.637 | 1/98 |
| | PDAIF | 10.238 | 1 | 9.818 | 1 | 9.858 | 1 | 8.527 | 1 | 7.524 | 2 | 9.193 | 1/98 |
| J FINANC ECON | JIF | 5.162 | 2 | 4.505 | 2 | 3.541 | 2 | 4.047 | 2 | 3.769 | 2 | 4.205 | 2/98 |
| | PDAIF | 7.376 | 3 | 8.090 | 2 | 7.212 | 2 | 6.792 | 3 | 6.819 | 3 | 7.258 | 2/98 |
| J ACCOUNT ECON | JIF | 3.282 | 6 | 3.839 | 3 | 3.535 | 3 | 2.724 | 4 | 2.833 | 5 | 3.243 | 4/98 |
| | PDAIF | 7.648 | 2 | 6.471 | 4 | 5.692 | 4 | 6.897 | 2 | 6.750 | 4 | 6.692 | 3/98 |
| REV FINANC STUD | JIF | 4.270 | 4 | 3.689 | 4 | 3.119 | 4 | 3.174 | 3 | 3.532 | 3 | 3.557 | 3/98 |
| | PDAIF | 6.557 | 4 | 5.635 | 6 | 6.049 | 3 | 5.762 | 4 | 7.936 | 1 | 6.388 | 4/98 |
| J ACCOUNT RES | JIF | 4.542 | 3 | 3.000 | 6 | 2.243 | 10 | 2.384 | 5 | 2.449 | 6 | 2.924 | 5/98 |
| | PDAIF | 5.129 | 8 | 5.740 | 5 | 4.192 | 7 | 3.904 | 7 | 3.608 | 7 | 4.515 | 7/98 |
| ACCOUNT REV | JIF | 2.245 | 13 | 2.304 | 10 | 1.953 | 15 | 2.267 | 6 | 2.234 | 7 | 2.201 | 8/98 |
| | PDAIF | 4.664 | 9 | 5.432 | 7 | 5.041 | 5 | 3.708 | 9 | 3.574 | 8 | 4.484 | 8/98 |
| ACAD MANAGE REV | JIF | 8.855 | 2 | 9.408 | 2 | 7.288 | 2 | 7.475 | 2 | 7.817 | 1 | 8.169 | 2/210 |
| | PDAIF | 15.481 | 2 | 14.136 | 2 | 14.300 | 2 | 14.597 | 1 | 10.068 | 5 | 13.716 | 2/210 |
| ACAD MANAGE J | JIF | 6.700 | 4 | 7.417 | 5 | 6.233 | 3 | 6.448 | 3 | 4.974 | 5 | 6.354 | 4/210 |
| | PDAIF | 12.925 | 5 | 14.030 | 4 | 13.553 | 4 | 11.838 | 5 | 10.900 | 3 | 12.649 | 3/210 |
| ADMIN SCI QUART | JIF | 5.878 | 9 | 4.929 | 13 | 5.316 | 6 | 3.333 | 21 | 2.394 | 34 | 4.370 | 14/210 |
| | PDAIF | 11.290 | 7 | 8.667 | 12 | 7.179 | 10 | 13.500 | 2 | 12.241 | 1 | 10.575 | 6/210 |
| STRATEGIC MANAGE J | JIF | 5.482 | 12 | 4.461 | 17 | 3.380 | 21 | 3.341 | 20 | 2.993 | 18 | 3.931 | 19/210 |
| | PDAIF | 9.010 | 13 | 8.695 | 10 | 7.093 | 11 | 7.415 | 11 | 7.790 | 8 | 8.001 | 11/210 |
| J INT BUS STUD | JIF | 6.198 | 6 | 5.869 | 8 | 3.620 | 18 | 3.563 | 17 | 3.594 | 12 | 4.569 | 10/210 |
| | PDAIF | 9.240 | 12 | 8.678 | 11 | 5.931 | 16 | 6.617 | 15 | 6.443 | 15 | 7.382 | 15/210 |
| ORGAN SCI | JIF | 3.027 | 56 | 2.691 | 54 | 3.360 | 22 | 3.775 | 14 | 3.807 | 9 | 3.332 | 26/210 |
| | PDAIF | 6.140 | 32 | 6.874 | 23 | 7.873 | 9 | 7.246 | 12 | 7.038 | 10 | 7.034 | 17/210 |
| MIS QUART | JIF | 5.430 | 1 | 7.268 | 1 | 5.384 | 1 | 5.311 | 1 | 5.405 | 1 | 5.760 | 1/88 |
| | PDAIF | 11.554 | 1 | 14.135 | 1 | 11.946 | 1 | 11.034 | 1 | 11.158 | 1 | 11.965 | 1/88 |
| INFORM SYST RES | JIF | 2.301 | 24 | 2.763 | 14 | 3.047 | 5 | 2.436 | 6 | 2.322 | 7 | 2.574 | 11/88 |
| | PDAIF | 7.528 | 2 | 5.902 | 6 | 4.157 | 6 | 4.743 | 3 | 5.549 | 3 | 5.576 | 4/88 |

[a] The number of journals in each category is based on the 2017 JCR data.
Note: Journals are sorted according to their PDAIF ranking in their categories.

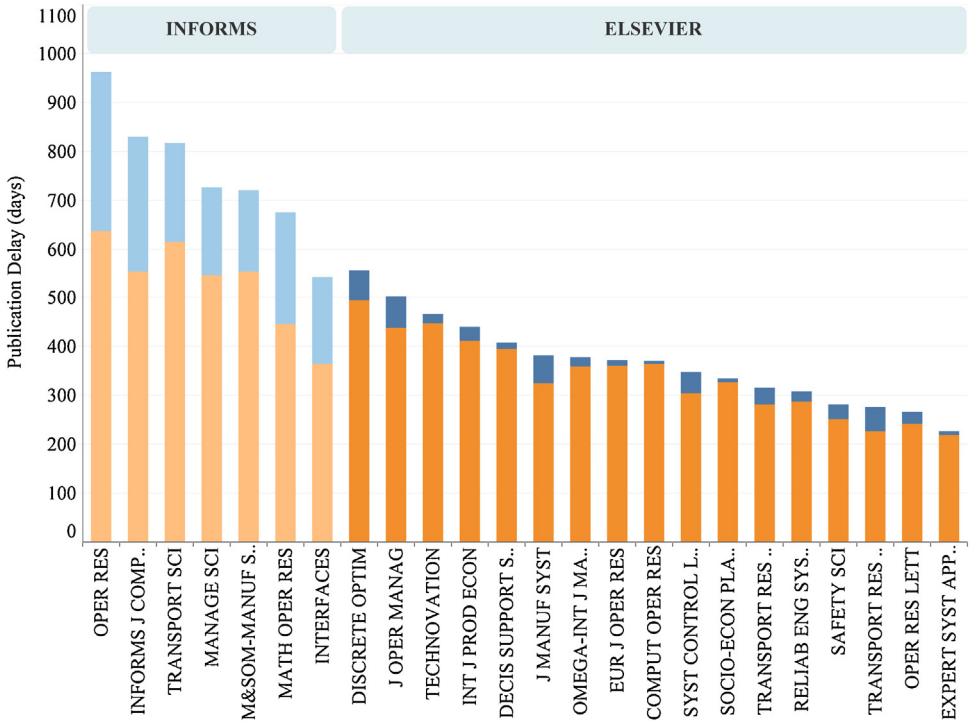



**Fig. 6.** Delay information for journals in the OR&MS category published by *INFORMS* and *ELSEVIER*. *Note*: The orange bar is the time gap from "Received" to "Accepted", and the blue bar is time gap from "Accepted" to "Published Online". (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Detailed comparison results of PDAIF and JIF for journals on the UTD 24 list are given in Table 3. For a better visual illustration, the numeric and ranking comparisons between PDAIF and JIF are visualized in Fig. 5. The 5-year JIF results for these journals are also included for comparison.

Fig. 5 shows that every journal has a significantly increased impact factor using PDAIF, and most journals on the UTD 24 list are now ranked into the first quartile in their categories. For low-ranking journals, the 5-year JIF rank is still lower than that of PDAIF, which shows that publication delay still has a significant impact over it. In addition, PDAIF is always higher than JIF and 5-year JIF numerically. Following the detailed results from 2013 to 2017 of Table 3, we can see that there are 25 instances from seven journals of the total 120 cases in which the JIF rankings are out of the first quartile, which constitutes a percentage of 20.83%. In contrast, PDAIF reduces this percentage to 7.50%, only 9 out of 120 instances. When looking at the average impact factor and ranking, only two journals fall out of the first quartile. Furthermore, Fig. 5 gives a clear comparison between JIF, 5-year JIF, and PDAIF. These results indicate that there is a high consistency between the PDAIF ranking and reputation-based top journal list, and PDAIF provides an evolutionary revision of JIF which evaluates journals more precisely.

Among the seven journals that fall out of the first quartile with JCR's JIF ranking, six of them (*OPER RES*, *M&SOM-MANUF SERV OP*, *INFORMS J COMPUT*, *MARKET SCI*, *ORGAN SCI*, and *INFORM SYST RES*) are published by *INFORMS* (the Institute for Operations Research and the Management Sciences). This unexpected finding motivates further investigation of the influence of publishing strategies of publishers, from the perspective of journals' impact factor and publication delay. In the following section, we perform a case study analyzing two groups of journals published by *ELSEVIER* and *INFORMS*.

## 6. Case study

Previous sections of this paper have discussed the effect of the average publication delay of a category and proposed PDAIF, which takes publication delay into account. Compared to JIF, PDAIF delivers higher impact factors for journals and matches reputation-based top journal lists with better accuracy. We now investigate the mediation effect of the publication delay of each journal on its own PDAIF.

Two large academic publishers, *ELSEVIER* and *INFORMS*, which both publish high-quality scientific journals, provide us a good research sample with differentiated groups in the OR&MS category of JCR. There are a total of 84 journals in this category, 17 of which are published by *ELSEVIER* and seven by *INFORMS*. Fig. 6 shows the detailed publication delay information for these 24 journals (publication information for journals not included in the UTD 24 journal list are randomly sampled from their official websites with a 10% size of all available items). It is clear that the delays of *ELSEVIER* journals are much lower

**Table 4**
JIF and journal ranking for OR&MS journals published by *ELSEVIER* and *INFORMS*.

| Journal | Publisher | JIF | Ranking | Journal | Publisher | JIF | Ranking |
|---|---|---|---|---|---|---|---|
| J OPER MANAG | ELSEVIER | 4.899 | 1 | TRANSPORT RES E-LOG | ELSEVIER | 3.289 | 14 |
| TECHNOVATION | ELSEVIER | 4.802 | 2 | COMPUT OPER RES | ELSEVIER | 2.962 | 15 |
| INT J PROD ECON | ELSEVIER | 4.407 | 3 | SAFETY SCI | ELSEVIER | 2.835 | 16 |
| OMEGA-INT J MANAGE S | ELSEVIER | 4.311 | 5 | SYST CONTROL LETT | ELSEVIER | 2.656 | 19 |
| RELIAB ENG SYST SAFE | ELSEVIER | 4.139 | 6 | OPER RES | INFORMS | 2.263 | 25 |
| TRANSPORT RES B-METH | ELSEVIER | 4.081 | 7 | M&SOM-MANUF SERV OP | INFORMS | 1.795 | 34 |
| EXPERT SYST APPL | ELSEVIER | 3.768 | 8 | SOCIO-ECON PLAN SCI | ELSEVIER | 1.610 | 40 |
| J MANUF SYST | ELSEVIER | 3.699 | 9 | INFORMS J COMPUT | INFORMS | 1.392 | 47 |
| DECIS SUPPORT SYST | ELSEVIER | 3.565 | 10 | MATH OPER RES | INFORMS | 1.078 | 62 |
| MANAGE SCI | INFORMS | 3.544 | 11 | INTERFACES | INFORMS | 0.889 | 68 |
| EUR J OPER RES | ELSEVIER | 3.428 | 12 | OPER RES LETT | ELSEVIER | 0.643 | 76 |
| TRANSPORT SCI | INFORMS | 3.338 | 13 | DISCRETE OPTIM | ELSEVIER | 0.480 | 79 |

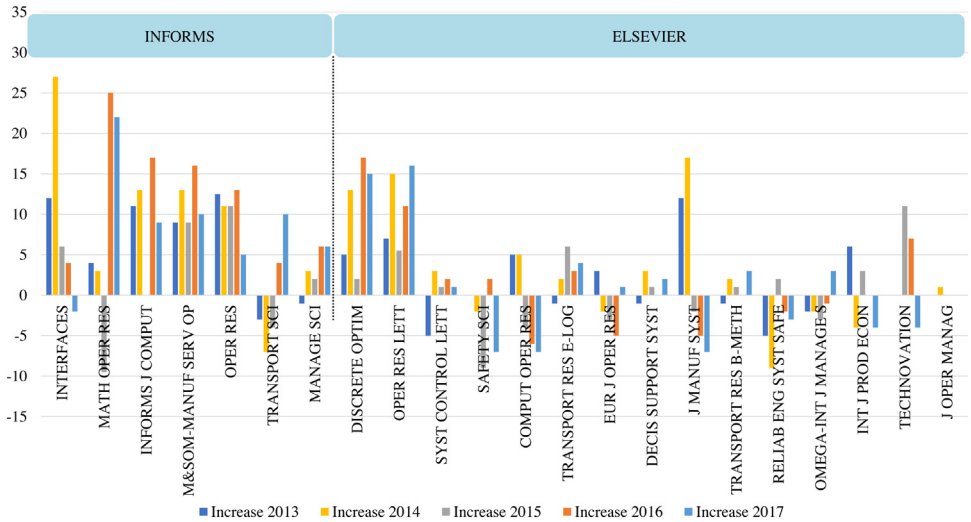



**Fig. 7.** PDAIF rank changes of journals compared with JIF ranking for journals published by *INFORMS* and *ELSEVIER*. *Note*: Journals are sorted in decreasing order of JIF ranking in 2017 for each publisher.

than *INFORMS* journals. Specifically, the average delay of *INFORMS* journals is 753 days, which is double the 366-day average delay of *ELSEVIER* journals.

The 2017 JIF rankings of these 24 journals are listed in Table 4. From this table, on the one hand, we can see that 14 of the 17 journals published by *ELSEVIER* are ranked in Q1 (the first quartile with 21 journals among 84 journals in OR&MS category). In contrast, among the other seven journals published by *INFORMS*, only *MANAGE SCI* and *TRANSPORT SCI* are ranked in Q1. On the other hand, when we looking at the reputation-based top journal list for this field (i.e., the UTD 24 journal list), four of the seven journals published by *INFORMS* are on the list, while only one *ELSEVIER*-published journal is on the list. Furthermore, among the four *INFORMS*-published UTD-journals, only one of them is ranked in the Q1 quartile (*MANAGE SCI*, and it is ranked 11th among 84 journals). This finding shows considerable inconsistency between JIF ranking and the reputation-based top journal list.

Consequently, we are interested in seeing how well PDAIF performs compared with the ranking based on JIF. PDAIFs for all the 84 journals in the OR&MS category were calculated according to Eq. (3), and the ranking changes for the journals on the UTD 24 journal list from 2013 to 2017 are shown in Fig. 7. As we can see, the rank changes for most *ELSEVIER*-published journals, swinging up and down among journals and years (except for *DISCRETE OPTIM* and *OPER RES LETT*, which are ranked 79 and 76 among the 84 journals). In contrast, all *INFORMS*-published journals show stable and considerable increases in ranks among journals and years. This implies that PDAIF will increase the rank for journals with long publication delays and provide a more reasonable journal ranking compared with JIF.

## 7. Conclusions

In this section, we first provide implications and suggestions to reduce the negative influence of publication delay. Then this paper concludes with suggestions for future research directions.

### 7.1. Discussion and implications

In this paper, we have demonstrated the effect of publication delay on the most influential academic evaluation system, JIF. This influence leads to a mismatch between JIF ranking and reputation-based top journal lists that are created by peer-scholars. This mismatch reveals the inaccuracy of the JIF evaluation system and the disordered situation that academia is facing. Through modeling the review and JIF calculation process, we explain how publication delay influences the JIF: it invalidates substantial citations that should have affected the impact factor and brings into citations added during the review process. The longer the publication delay, the more inaccurate the JIF evaluation result. What is more, according to our data collected from the journals' official websites, the average publication delay of journals on the UTD 24 list is longer than two years, and this explains why these elite journals do not have impressive impact factors.

To eliminate the negative effect of publication delay, a publication delay adjusted impact factor (PDAIF) is proposed to calculate the journal impact factor. Our study proves that PDAIF produces significant impact factor increases compared with JIF, as well as a more accurate ranking consistent with reputation-based journal list. Finally, based on a case study of journals published by *INFORMS* and *ELSEVIER*, we see that the PDAIF will bring more impact factor increase for journals with longer publication delay by eliminating the delay's negative influence.

Based on our previous analysis and discussion, the following suggestions are provided to reduce the negative influence of publication delay. First of all, journal publishers are encouraged to shorten the publication delay for their journals to improve their journals' impact factors. As we can see from Fig. 6, for example, *INFORMS*-published journals have considerable time gaps from "Accept" to "Published Online", and the publication delay can be shortened about 220 days if the accepted articles can be published online immediately, which is feasible in modern digital times. Secondly, editorial offices are advised to speed up the review cycle and expand journal volumes to shorten the publication delay. Applicable strategies, for example, shortening the time window for reviewers with allowed extensions, will draw more attention from the reviewers to complete the task. This strategy is also applicable for authors, to stimulate them to finish revisions as soon as possible.

### 7.2. Future research directions

There is no perfect metric to evaluate all journals justifiably, equitably, and accurately. The inaccuracy of JIF is caused by various, complicated factors, and this research only studied the effect of publication delay, which is defined as the time gap between the submission and publishing of an article in this paper. However, often a paper that is rejected by (or withdrawn from) one journal will be submitted to a different one. This implies that the publication delay of a given article may be much longer than the data we have collected since the paper's submission history to other journals is uncollectible and unquantifiable at present. Perhaps this issue can be resolved by changing the technology for paper submissions.

Insightful future research may proceed in the following directions. Firstly, the influence of PDAIF for journals in different disciplines is worthy of investigation. Secondly, implementing the influence of publication delay on other time-based evaluation metrics is also of interest. For example, journal rankings based on the *5-Year Impact Factor* or *Immediacy Index* also show considerable inconsistency with reputation-based journal lists. Taking publication delay into consideration to modify these may yield more accurate metrics.

## Author contributions

**Xiaolong Guo:** conceived and designed the analysis, collected the data, contributed data or analysis tools, performed the analysis, wrote the paper: Original draft; review and editing, other contribution: Funding acquisition.

**Xiaoxiao Li:** collected the data, contributed data or analysis tools, performed the analysis, wrote the paper: Original draft.

**Yugang Yu:** contributed data or analysis tools, wrote the paper: review and editing, other contribution: Funding acquisition.

## Declarations of conflicts of interest

None declared.

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