# Impact factor based on logarithmic correction for papers' citations and studies on its category normalization

**Liu Xueli [1,2,*] and Guo Jia [3]**
[1] Henan Research Center for Science Journals,
Xinxiang Medical University, Xinxiang, Henan, PR CHINA
[2] Faculty of Humanities and Social Sciences,
Xinxiang Medical University, Xinxiang, Henan, PR CHINA
[3] Management Institute, Xinxiang Medical University,
Xinxiang, Henan, PR CHINA
e-mail: *lxl@xxmu.edu.cn (corresponding author); liueditor@163.com
ORCID ID: L. Xueli: 0000-0001-7055-674X
G .Jia: 0000-0002-8700-7269

## ABSTRACT

*The objective of this study is to address the disciplinary variations in Journal Impact Factor (JIF), enabling its reasonable application in the evaluation of journals across diverse disciplines. To achieve this, the study utilized journals indexed in the Journal Citation Reports and considered papers from eight distinct disciplines as the research subjects. The citations of papers within each academic field were transformed into normal distributions, each with a different base logarithm. Subsequently, the logarithm-corrected impact factor ($IF_{log}$) for each journal was calculated. Category normalization for the $IF_{log}$ ($cnIF_{log}$) was conducted by dividing each journal's $IF_{log}$ by the logarithmic correction aggregate impact factor of the discipline to which it belongs and the superiorities of $cnIF_{log}$ in the evaluation of academic journals across different disciplines were demonstrated empirically. The results showed that taking different base logarithms could convert the citations of the journal papers into an approximately normal distribution. The $IF_{log}$ of the eight disciplines' journals was normally distributed, and the $IF_{log1.5}$, $IF_{ln}$, $IF_{log5}$, and $IF_{log10}$ of the journals were 100% positively related (r=1.000, P=0.000) both in the same and different disciplines. Compared with the impact factor ($IF_{2018}$), average impact factor percentile (aJIFP), journal index of PR8 (JIPR8), $IF_{log}$ and relative impact factor ($rIF_{2018}$), and other indicators, $cnIF_{log1.5}$ exhibits the least variation among the journals from the eight different fields. In comparison to aJIFP and JIPR8, it demonstrates the highest correlation, ideal discrimination, and stability.It is concluded that $cnIF_{log1.5}$ is an ideal journal evaluation indicator in same or different disciplines.*

**Keywords:** Citation analysis; Journal Impact Factor; Standardization Impact Factor; Journal Evaluation; Journal Quartile

## INTRODUCTION

For a long time, the prevalence of the global Science Citation Index (SCI) phenomenon and the impact factor worship (Liu 2012) have led to widespread misuse (Simons 2008; Wang, Fang, and Wang 2015) and abuse (Katritsis 2019) of this metric. Regrettably, the impact factor, originally intended for journal evaluation, is often used to assess researchers (Ye 2015). The root cause of this misuse and abuse can be traced back to inherent design flaws (Malan 2022). The most evident and noticeable earlier flaw is that its calculation violates the principles of statistics: arithmetic mean used to characterize each paper's overall level of citations in a journal that exhibits a skewed distribution (Vanclay 2012; Liu et al. 2019). In addition, the calculation of the impact factor does not consider the huge differences between disciplines and cannot be applied to the evaluation of academic journals across different disciplines (Leydesdorff, Zhou and Bornmann 2013). However, the journal impact factor (JIF) is widely used domestically and globally for research evaluation (Kulczycki et al. 2022) and is often used in evaluating academic journals across different disciplines. For instance, within German universities, the cumulative impact factor of journals in which scientists publish their research papers is typically aggregated to ascertain the research funding allocated to a department. In Finland, the government provides funding to support research at university hospitals, and to some extent, this allocation is influenced by the impact factor of journals in which researchers publish their work (Adam 2002). Oelrich, Peters and Jung (2007) conducted a study using the 15 European Union (EU) member countries as their research subjects. They calculated the cumulative impact factor of each country by aggregating the impact factors of journals in which their papers were published. Subsequently, they assessed the research performance of each country based on this cumulative impact factor. Additionally, impact factors are commonly employed as evaluation criteria in documents related to professional title promotion, scientific research awards, talent assessments, and other official documents issued by Chinese universities.

On February 20, 2020, the Ministry of Education and the Ministry of Science and Technology jointly issued the "Several opinions on regulating the use of related indexes of SCI papers in colleges and universities and establishing correct evaluation guidance". This document garnered significant attention within the Chinese academic community (Hu 2020; Wang and Yuan 2020). Its primary objective is not to eliminate SCI papers and associated evaluation metrics but rather to underscore the importance of "standardizing their usage" and rectifying any instances of their abuse and misuse, with a focus on the JIF, to the greatest extent possible. Therefore, to introduce a novel approach to standardize JIF and offer diverse options for evaluating academic journals across various disciplines, this study addresses the significant limitations of the impact factor. It calculates the impact factor for each journal by applying a normal conversion method to account for the skewed distribution of citations in scientific journal papers. Subsequently, we perform discipline-specific standardization adjustments to enhance the scientific and rational aspect of JIF standardization, aiming to establish a scientific basis for the judicious utilization of the impact factor.

## LITERATURE REVIEW

The literature review centers on several key aspects of studies related to JIF. These include the current state of research on disciplinary standardization of JIF, investigations into relative impact factors, the ranking of JIF, and the calculation of JIF percentiles. It also delves into the logarithmic correction impact factor and its role in the design of disciplinary standardization. Additionally, the review explores the theoretical underpinnings behind the design of the logarithmic correction impact factor. Finally, it introduces disciplinary standardization impact factors along with their corresponding mathematical expressions.

### Progress in Research on Disciplinary Standardization of JIF

Notably, there are evident differences in citation rates and the JIF within various academic disciplines (Traylor and Herrmann-Lingen 2023). For example, as Mingers et al. (2015) pointed out, in the field of management, the citations of strategic management papers are approximately four times that of public management papers; in the field of biological sciences, the journal impact factor is much higher than that of mathematics journals (Hsu and Huang 2012); the impact factor of nano-scale science and technology journals is approximately ten times that of history journals (Liu et al. 2017). The ultimate causes for this can be attributed to variations in bibliometric characteristics across disciplines, which are influenced by a range of factors. These distinctions are notably evident in the following aspects:

(i) Differences in the nature of disciplines: For instance, the field of natural sciences typically exhibits significantly higher citation rates and impact factors compared to the field of social sciences.

(ii) Divergent stages of disciplinary development: For instance, within the broader category of Information Science & Library Science, notable variations in citation levels exist among three subfields - traditional library science, information systems, and publishing and communication - owing to the distinct historical periods when they initially emerged (Raban, Gordon and Geifman 2011).

(iii) Differences in literature aging speed: For instance, the cited half-life of journals in Information Science & Library Science is generally three years, whereas that in history fields is roughly 8–10 years.

(iv) Differences in the proportion of the types of scientific papers: The literature's category influences its citation potential. In general, review papers tend to garner more citations than research papers, and disciplines with a greater prevalence of review papers are more inclined to exhibit higher citation rates. (Tahamtan, Safipour Afshar and Ahamdzadeh 2016).

The pursuit of interdisciplinary journal evaluation has prompted research on the standardization of the impact factor across different academic disciplines. The standardization method mainly includes three aspects, which are described in the following sub-sections.

### (a) Relative Impact Factor

Relative impact factor (rIF) refers to the impact factor of a journal divided by the characteristic value of the JIF in the discipline of the journal (mainly refers to the discipline journal's maximum, average, and median impact factors) (Vinkler 2012; Sun and Yuan 2020). The research in this area is the earliest and the most direct method of disciplinary standardization of the impact factors. Sen (1992) initially suggested computing the rIF by dividing a specific journal's impact factor by the maximum impact factor within its discipline. Logan (2016) reemphasized the utilization of this standardization method for JIFs. Additionally, Marshakiva-Shaikevich (1996) introduced an alternative approach to disciplinary standardization by dividing a journal's impact factor by the average impact factor of the top five journals within its respective discipline. Chinese scholars, Xiong (2005) and Yang (2008), among others, have successively proposed to take the result of dividing the impact factor of a journal by the average of the impact factors of all journals in the same discipline as the rIF. Liu et al. (2017) attempted to divide the impact factor of a journal by the median and aggregate impact factors in the discipline of the journal to conduct disciplinary standardization processing.

As the distribution of the impact factor values of journals of different disciplines is different and almost all of them are not normally distributed (Yu, Yuan and Wang 2018), dividing the JIF by the maximum, median, average, or aggregate impact factor of the discipline to perform disciplinary standardization processing can yield notably distinct outcomes, all of which lack scientific rigour. For example, if the impact factor of a journal ranked first in a discipline is extremely high, and the rIF is calculated by dividing the JIF by the discipline's maximum impact factor, the rIF of other journals in the discipline will be significantly lower than the rIF of journals in other disciplines. Abramo and D'Angelo (2016) believe that it is futile to divide the impact factor of each journal by the average or median impact factor of the discipline for disciplinary standardization.

### (b) Journal Impact Factor Ranking

In 1999, academician Zou Chenglu (Zou 1999) first proposed in *The Science Times* that journals in a discipline should be divided into three areas: high, medium, and low according to the high-low of impact factors. In 2001, the National Science Library, Chinese Academy of Sciences first issued the method for journal ranking (the Chinese Academy of Sciences' journal ranking), dividing SCI journals into four categories (Wang 2013) with the purpose of disciplinary standardization processing of the impact factor of journals in different disciplines. Journals in the same subarea have roughly the same status and influence in their respective disciplines, making journals of different disciplines comparable to some extent.

In the Journal Citation Report (JCR), the journal ranking from 2003 was added in February 2009, which was scientific and objective (Jiang 2010). The JCR database also divides journals into four categories. Quartile 1 (Q1) includes the top 25% of journals ranked by impact factor; Quartile 2 (Q2) encompasses journals ranked between the top 25% and 50%; Quartile 3 (Q3) represents journals ranked between the top 50% and 75%; while Quartile 4

(Q4) comprises the remaining 25% of journals with lower impact factors (Garcia, Rodriguez-Sánchez, Fdez-Valdivia and Martinez-Baena 2012; Liu, Hu and Gu 2016).

Journal ranking serves as a straightforward assessment of academic journals across various disciplines, akin to a qualitative grading system. Each JCR partition typically consists of around 2500 journals. Within the same discipline and partition, there exists a multitude of journals, and their impact factors can significantly differ. Consequently, journal ranking may not provide a precise evaluation of academic journals across diverse disciplines.

### (c) Journal Impact Factor Percentile

In 2004, Pudovkin and Garfield (2005) proposed the rank-normalized impact factor (rnIF). The calculation formula is as follows:

$$rnIF = \frac{K - R + 1}{K} \tag{1}$$

In Eq (1), *K* is the total number of journals in a certain discipline, and *R* is the ranking of the impact factor of a certain journal in descending order of the corresponding discipline. Obviously, the higher the ranking of journals in the same discipline, the greater the rnIF value is. This is the disciplinary standardization of the impact factor that the JIF creator, Eugene Garfield, directly participated in. A new bibliometric indicator in the JCR in 2015 is the journal impact factor percentile (JIFP). Its calculation formula is as follows:

$$JIFP = \frac{N - R + 0.5}{N} \tag{2}$$

In Eq (2), *N* is the total number of journals in a certain discipline, and *R* is the ranking of the impact factor of a certain journal in the discipline in descending order. The effect of adding 0.5 to the numerator is to prevent JIFP=0 when *R*=*N* (that is, the last journal in each disciplinary ranking). Eq (2) almost completely inherits the design concept of the impact factor disciplinary standardization of Eq (1), but the additional constant in the numerator is changed from 1 to 0.5, which has a smaller impact on the calculation results. The rnIF and JIFP almost share the same meaning, mainly representing the ranking position of a JIF in the discipline to which it belongs. Their purpose is to set a completely quantitative evaluation index for evaluating academic journals across different disciplines (Liu, Wei and Meng 2018). Yu (2016) introduced the characteristics of the JIFP in detail and believed that the most significant advantage of the JIFP was that through standardized transformation, the relative position of each journal in the discipline was obtained, which could facilitate comparison between different disciplines.

However, the JIFP also has evident shortcomings. We can find from Eq (2) that for journals with the same impact factor ranking in different disciplines, the size of the JIFP is completely determined by the total number of journals in the discipline. This will lead to the underestimation (or overestimation) of excellent journals in small (or large) disciplines. In addition, the JIFP only considers the ranking of the JIF, ignoring the degree of difference in impact factor values (Liu, Wei and Meng 2018).

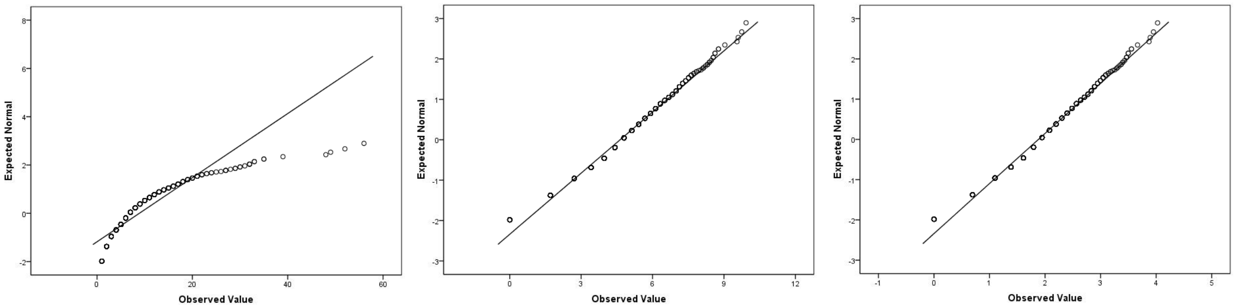
## The Logarithmic Correction Impact Factor and the Design of Disciplinary Standardization

### (a) Theoretical basis of the logarithmic correction impact factor design

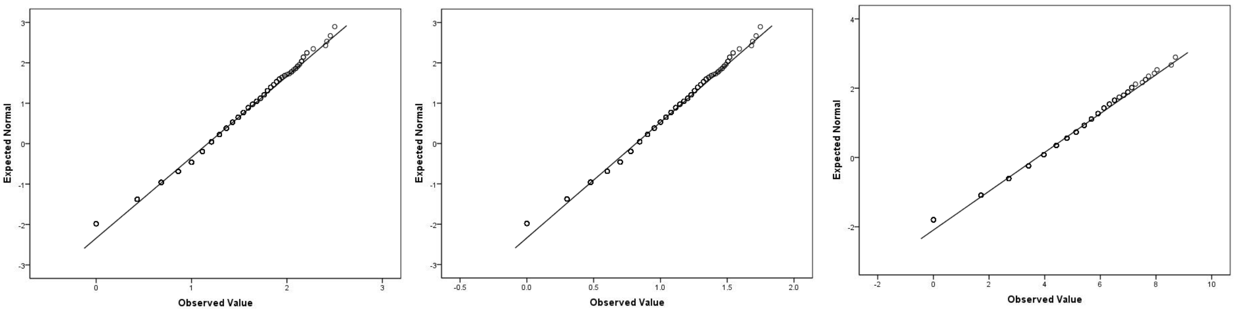
Journal ranking and JIFP serve as positional indicators, primarily reliant on the ranking position of JIFs within their respective disciplines. Their shared limitation is the disregard for variations in the actual influence of the journals. As an example, within the field of multidisciplinary studies, there are 64 journals (JCR-2018), with the top three being *Nature, Science,* and *Nature Communications.* In 2018, their respective impact factors were 40.137, 37.205, and 12.124, and their JIFPs were 99.219, 97.656, and 96.094. Regardless of whether the impact factor of *Nature Communications* is high or not, as long as it maintains its third position, its JIFP remains at 96.094. The rIF is a purely quantitative index. However, since the essence of the impact factor lies in the average citations received by literature published in a specific journal during the preceding two years in a given statistical year, the citations for each journal do not follow a normal distribution. Consequently, utilizing average citations as the JIF contradicts statistical principles. Furthermore, the distribution of the JIF of most disciplines does not show a normal distribution. It is also contrary to statistical principles to calculate the rIF by dividing the impact factor of a certain journal by the average, median, aggregate, and maximum impact factors of its disciplinary journals. There is still great uncertainty in the effect of disciplinary standardization.

Numerous scholars (Yu, Yuan and Wang 2018; Thelwall 2016; Perneger 2015; Liu et al. 2021) have confirmed that journal citations can be transformed into normal or approximately normal distribution by taking the logarithm. The research of Lou, Wnag and Zhang (2019) proves that square root, third power, and the fourth power of the citations of papers can also transform citation distribution into a normal distribution. At present, there is no dispute about transforming the skewed distribution of citations of journal papers into a normal distribution. Whether the natural logarithm (Clauset, Shalizi, and Newman 2009) or the base-10 logarithm (Thelwall 2016) is employed, both transformations result in a favorable normalization effect on the distribution of citations.

The same conclusion was drawn after studying data distributions (Figures 1 and 2) after taking the logarithm of the citations of papers published in the geology, materials science, and biomaterials journals from 2016 to 2017. As shown in Figures 1 and 2, the citations of journal articles are markedly presented in skewed distribution (see Figures 1a and 2a). Citations can be converted to an approximately normal distribution through logarithmic transformation (regardless of the logarithm base). The size of the logarithm base has a minimal impact on the conversion effect. No visible difference can be observed between the cumulative citation ($C_t$) after two years and the annual citation ($C_{2018}$). Meanwhile, the impact factor calculated after the logarithmic transformation of citations is also presented in a normal distribution among the eight selected disciplines in this study (refer to the results of the empirical study). Hence, dividing the impact factor of each journal by the aggregate impact factor of the discipline to which it belongs is a scientific approach for disciplinary standardization.

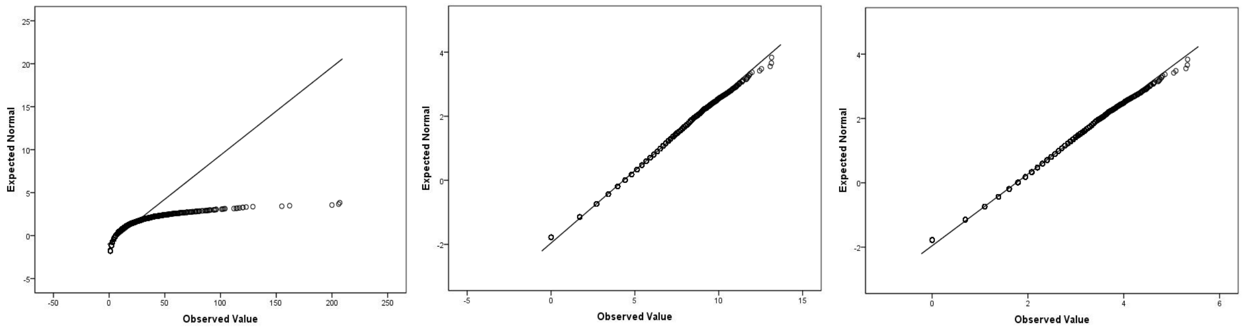



a. cumulative    b. $\log_{1.5}(C_t+1)$    c. $\ln(C_t+1)$

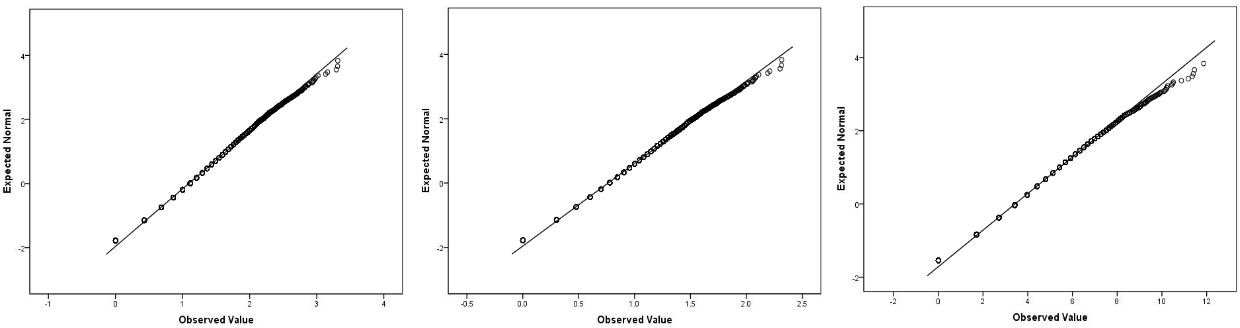



d. $\log_5(C_t+1)$    e. $\log_{10}(C_t+1)$    f. $\log_{1.5}(C_{2018}+1)$

Figure 1: Q–Q Plot Before and After the Logarithmic Transformation of Citations in *Geology* (Journal) from 2016 to 2017.




a. cumulative    b. $\log_{1.5}(C_t+1)$    c. $\ln(C_t+1)$




d. $\log_5(C_t+1)$    e. $\log_{10}(C_t+1)$    f. $\log_{1.5}(C_{2018}+1)$

Figure 2: Q–Q Plot Before and After the Logarithmic Transformation of Citations in Materials Science, and Biomaterials Journals (Discipline) from 2016 to 2017.

### (b) Disciplinary Standardization Impact Factors and their Mathematical Expressions

Impact factor based on logarithmic correction ($IF_{log}$) corrects the statistical defect of directly using the average citations of papers to calculate impact factors, and the $IF_{log}$ of the eight disciplinary journals selected in this study have a normal distribution. Therefore, it is statistically reasonable to divide the $IF_{log}$ of a certain journal by the $aIF_{log}$ (the logarithmic correction aggregate impact factor) of the discipline to which it belongs as the disciplinary standardization impact factor (category normalized impact factor, cnIF). The mathematical expression of cnIF is as follows:

$$cnIF_i = \frac{IF_{\log i}}{aIF_{\log i}} \tag{3}$$

In Eq. (3), $IF_{\log i}$ is the logarithmic correction impact factor of the *i*-th journal in a discipline, obtained from Eq. (4). $aIF_{\log i}$ is the average logarithmic correction citations of all items of the discipline to which it belongs.

$$IF_{\log_i} = \frac{\sum_{i=1}^{n} \log(C_i + 1)}{n} \tag{4}$$

In Eq. (4), $C_i$ is the citation of the *i*-th document of a journal in the statistical year, and *n* is the number of citable documents published in the previous two years of the journal. According to the difference of the logarithm base, the impact factor of logarithm correction is expressed as $IF_{log1.5}$, $IF_{ln}$, $IF_{log5}$, and $IF_{log10}$.

## MATERIALS AND METHOD

One of the objectives of this study is to correct the disciplinary differences of the JIF, enabling the adjusted impact factor to be suitably employed in the assessment of journals spanning various fields. To facilitate cross-disciplinary comparisons, this study encompasses multiple disciplines as its focus. As a result, the study incorporates a diverse selection of research subjects, comprising five journals from the natural sciences and three from the social sciences. It includes citable documents, encompassing research papers and reviews, published between 2016 and 2017. The following two aspects were considered in selecting the disciplines:

(i) The disciplinary scale should not be too small, and it is suitable for statistical treatment. The selected conditions are as follows: the number of journals > 30 and the number of citable documents > 2000; and

(ii) It includes fast-moving (the aging speed of the document is faster) and slow-moving (the aging speed of the document is slower) disciplines (Sundaram, Hodler and Rosenthal 2012) as far as possible, which is mainly reflected in the difference of field integrated cited half-life.

The finally selected natural science disciplines are Engineering, Environmental; Geology; Materials Science, Biomaterials; Ophthalmology; and Virology; disciplines of social science are Information Science & Library Science; Ethics; and History of Social Sciences. Table 1 presents information about the selected disciplines along with details about the journals within each discipline.

Table 1: The Selected Eight Disciplines and Associated Journals

| **Discipline** | **No. of journals** | **Citable documents** | **No. of paper per journal** | $C_{2018max}$ | $C_{2018mid}$ | $C_{2018ave}$ |
|---|---|---|---|---|---|---|
| Engineering, Environmental | 52 | 30825 | 592.8 | 189 | 4 | 5.687 |
| Geology | 46 | 5463 | 118.8 | 47 | 1 | 2.249 |
| Materials Science, Biomaterials | 32 | 15924 | 497.6 | 122 | 3 | 4.628 |
| Ophthalmology | 59 | 17695 | 299.9 | 126 | 1 | 2.341 |
| Virology | 36 | 12656 | 351.6 | 123 | 2 | 3.527 |
| Information Sci. & Library Sci. | 88 | 8814 | 100.2 | 178 | 1 | 2.388 |
| Ethics | 54 | 4395 | 81.4 | 84 | 1 | 1.625 |
| History of Social Sciences | 34 | 2053 | 60.4 | 11 | 0 | 0.695 |

*Note:* Journal number implies the number of journals in the discipline in the 2018 JCR; citable documents indicates the number of research articles and reviews in the discipline in 2016–2017; $C_{2018max}$ indicates the maximum value of citations of citable documents in the year 2018, $C_{2018mid}$ means median of citations, and $C_{2018ave}$ means average citation.

## Data Acquisition

Data acquisition was performed by accessing the Web of Science (WoS) database and designating SCI-Expanded and SSCI within the WoS core collection as the primary data sources. To compile an advanced search strategy for document retrieval, the ISSN numbers of journals belonging to the eight selected disciplines in JCR were utilized. Additionally, the time frame for document publication was established to encompass the years 2016 to 2017. For instance, the search strategy for engineering and environmental are IS=(0926-3373 OR 1385-8947 … … OR 0921-3449) AND PY=2016–2017. Through the "refine" function of the database, only the citable documents, namely Article and Review, are retained. Through "Create Citation Report," the citations of all papers in each year are derived, and the citations of each paper in 2018 ($C_{2018}$) are reserved for the calculation of the impact factor and other indicators.

## Normal Transformation of Citations' Distribution of Papers

The logarithmic method enables the normal transformation of citations' distribution of papers, serving two primary objectives:

(i) Upon taking the logarithm of citations, the data exhibit a well-fitting normal distribution, ensuring statistical validity in computing the average value of such data.

(ii) This transformation aims to ensure that the resulting data, after logarithmic adjustment, have a sufficiently wide range, enhancing the discriminatory power when calculating JIFs based on these transformed citation values.

As the size of the logarithm base directly determines the size of the transformed data, this study uses different bases (1.5, *e*, 5, 10) for logarithmic transformation and observes its effect. Furthermore, as many papers are not cited, and 0 has no logarithm, we add 1 to the citations of all papers before taking the logarithm.

The logarithmic method is expressed as $\log_{1.5}(C_t+1)$, $\ln(C_t+1)$, $\log_5(C_t+1)$, $\log_{10}(C_t+1)$, and $\log_{1.5}(C_{2018}+1)$, where $C_t$ is all citations to a certain journal from 2016 to 2018 to items published from 2016 to 2017 for calculating the cumulative impact factor (Liu 2016); $C_{2018}$ is citations to a certain journal in 2018 to items published from 2016 to 2017 to calculate the impact factor of each journal in 2018.

## *Calculation of cnIF*

According to Eq. (4), the $IF_{log}$ of each discipline's journal is calculated, and subsequently, the $IF_{log}$ is put into Eq. (3) to calculate the cnIF of each journal.

## *Selection of comparative indicators*

(i) $IF_{2018}$

The $IF_{2018}$ is all citations to the journal in 2018 to items published from 2016 to 2017, divided by the total number of all citable items (these comprise articles and reviews) published in the journal from 2016 to 2017, which is highly consistent with the impact factor of the JCR in 2018 ($r$=0.984, $P$=0.000). Therefore, the statistical analysis of this study uses $IF_{2018}$ to replace the impact factor of the 2018 edition of the JCR.

(ii) aJIFP

The JIFP is a new journal evaluation indicator introduced in the upgraded InCites JCR in 2015 (Yu 2016). This indicator is for transforming the ranking of the JIF into percentile values to realize the evaluation of academic journals across different disciplines (Liu et al. 2017; Clarivate Analytics 2020). The average JIF Percentile (aJIFP) is the average value of the JIFP of the journal in the discipline to which it belongs in the JCR, which comes from the 2018 edition of the JCR.

(iii) JIPR8

The Journal Index of Eight Percentile Rank Classes (JIPR8) refers to the quotient of the total PR8 score of citations for citable documents published by a journal within a specified time frame, divided by the total number of citable documents within that same time frame. The PR8 assignment method operates as follows: Based on the ascending order of percentile rankings for citations in the year 2018, the papers published by a journal from 2016 to 2017 are divided into eight percentile intervals, namely (0, 0.01%], (0.01%, 0.10%], (0.1%, 1.0%], (1.0%, 5.0%], (5.0%, 10.0%], (10.0%, 25.0%], (25.0%, 50.0%], and (50.0%, 100.0%]. Each interval is assigned a score of 100, 80, 60, 50, 40, 30, 20, and 10, respectively (with zero-cited papers receiving a score of 0).

(iv) $rIF_{2018}$

The $rIF_{2018}$ is the $IF_{2018}$ of certain journal divided by the aggregate impact factor of the discipline to which it belongs. It represents the simplest disciplinary standardization treatment for the impact factor of the journal.

### *Statistical methods*

Statistical Product and Service Solution (SPSS) version 18 was used for statistical data analysis. The Q–Q plot was employed for the normal transformation effect of journal citations; the Kolmogorov–Smirnov test was applied to evaluate the normal distribution of the JIF; Pearson and Spearman correlation analyses were applied to examine correlation between normal and non-normal distribution data, respectively; and the Kruakal–Wallis test is used to evaluate the difference of each indicator among journals in different partitions. The significance level for all tests was set at $\alpha$=0.05.

## RESULTS

### Logarithmic Correction Impact Factor of Journals of the Same Discipline and their Comparison with the Traditional Impact Factor

Taking Information Science & Library Science as an example, the logarithmic correction impact factors of different bases (1.5, *e*, 5, 10) in each journal are calculated, including $IF_{ln}$, $IFlog_{1.5}$, $IF_{log5}$, and $IF_{log10}$, as shown in Table 2.（In the Information Science & Library Science, there are a total of 88 journals. However, due to space constraints, we have included only the top 30 ranked journals in the table）. According to the statistical analysis of the indexes in Table 2, it is found that the $IF_{2018}$ and $rIF_{2018}$ of the journals of this discipline do not show a normal distribution, and the logarithmic correction impact factor of different bases are all normal distributions. There was a 100% correlation between the logarithmic correction impact factor of different bases (Pearson correlation analysis, *r*=1.000, *P*=0.000) and a high correlation between the logarithmic correction impact factor of different bases and $IF_{2018}$ (Spearman correlation analysis, *r*=0.994 , *P*=0.000). The logarithmic correction impact factor has the following characteristics:

(i) The value of the impact factor after correction is smaller than that of the impact factor, and the larger the base of logarithm, the smaller the logarithmic correction impact factor;

(ii) In terms of journal ranking, the logarithmic correction impact factor of different bases is significantly different, but the journal ranking is the same (there is no exception in Information Science & Library Science);

(iii) There is a significant discrepancy between the logarithmic correction impact factor of each journal and the traditional impact factor in ranking. More than half of the journals (58 out of 88) have experienced changes in their rankings, with the highest discrepancy being 10 positions.

To make the value of the corrected impact factor not too small to maintain the discrimination of the journal evaluation, this study chooses 1.5 as the base to take the logarithm of citations and correct the impact factor.

Among the eight selected disciplines, the $IF_{log1.5}$ of each discipline's journal shows a normal distribution, and the results of Kolmogorov–Smirnov test are as follows: Virology, *Z*=0.583, *P*=0.886; Geology, *Z*=1.178, *P*=0.124; Engineering and Environmental, *Z*=0.726, *P*=0.668; Materials Science and Biomaterials, *Z*=0.389, *P*=0.998; Ophthalmology, *Z*=0.797, *P*=0.549; Information Science & Library Science, *Z*=0.681, *P*=0.742; Ethics, *Z*=0.443, *P*=0.990; History of Social Sciences, *Z*=0.580, *P*=0.889.

Table 2: Logarithmic Correction Impact Factor and $IF_{2018}$ of 30 Information Science & Library Science Journals in the JCR

| **Abbreviated Journal Title** | **$IF_{2018}$** | **$IF_{2018}$ rank** | **$IF_{ln}$** | **$IF_{ln}$ rank** | **$IF_{log1.5}$** | **$IF_{log1.5}$ rank** | **$IF_{log5}$** | **$IF_{log5}$ rank** | **$IF_{log10}$** | **$IF_{log10}$ rank** |
|---|---|---|---|---|---|---|---|---|---|---|
| INT J INFORM MANAGE | 5.879 | 1 | 1.556 | 1 | 3.836 | 1 | 0.967 | 1 | 0.676 | 1 |
| J COMPUT-MEDIAT COMM | 5.563 | 2 | 1.523 | 2 | 3.755 | 2 | 0.946 | 2 | 0.661 | 2 |
| GOV INFORM Q | 5.287 | 3 | 1.472 | 3 | 3.629 | 3 | 0.914 | 3 | 0.639 | 3 |
| MIS QUART | 4.891 | 5 | 1.469 | 4 | 3.624 | 4 | 0.913 | 4 | 0.638 | 4 |
| J KNOWL MANAG | 4.893 | 4 | 1.425 | 5 | 3.516 | 5 | 0.886 | 5 | 0.619 | 5 |
| J STRATEGIC INF SYST | 4.424 | 8 | 1.424 | 6 | 3.513 | 6 | 0.885 | 6 | 0.619 | 6 |
| INFORM SYST J | 4.224 | 10 | 1.422 | 7 | 3.506 | 7 | 0.883 | 7 | 0.617 | 7 |
| INFORM MANAGE-AMSTER | 4.633 | 6 | 1.419 | 8 | 3.500 | 8 | 0.882 | 8 | 0.616 | 8 |
| INFORM PROCESS MANAG | 4.284 | 9 | 1.397 | 9 | 3.446 | 9 | 0.868 | 9 | 0.607 | 9 |
| J AM MED INFORM ASSN | 4.480 | 7 | 1.378 | 10 | 3.398 | 10 | 0.856 | 10 | 0.598 | 10 |
| J INF TECHNOL-UK | 4.175 | 11 | 1.261 | 11 | 3.111 | 11 | 0.784 | 11 | 0.548 | 11 |
| TELEMAT INFORM | 3.976 | 12 | 1.245 | 12 | 3.070 | 12 | 0.773 | 12 | 0.541 | 12 |
| J INFORMETR | 3.770 | 13 | 1.225 | 13 | 3.021 | 13 | 0.761 | 13 | 0.532 | 13 |
| J MANAGE INFORM SYST | 3.392 | 16 | 1.221 | 14 | 3.013 | 14 | 0.759 | 14 | 0.530 | 14 |
| INT J GEOGR INF SCI | 3.570 | 14 | 1.171 | 15 | 2.887 | 15 | 0.727 | 15 | 0.508 | 15 |
| J ASSOC INF SYST | 3.534 | 15 | 1.167 | 16 | 2.879 | 16 | 0.725 | 16 | 0.507 | 16 |
| EUR J INFORM SYST | 3.270 | 17 | 1.157 | 17 | 2.854 | 17 | 0.719 | 17 | 0.503 | 17 |
| MIS Q EXEC | 3.176 | 18 | 1.121 | 18 | 2.764 | 18 | 0.696 | 18 | 0.487 | 18 |
| INFORM ORGAN-UK | 3.000 | 21 | 1.115 | 19 | 2.750 | 19 | 0.693 | 19 | 0.484 | 19 |
| SOC SCI COMPUT REV | 3.033 | 20 | 1.101 | 20 | 2.716 | 20 | 0.684 | 20 | 0.478 | 20 |
| INT J COMP-SUPP COLL | 2.794 | 25 | 1.094 | 21 | 2.697 | 21 | 0.679 | 21 | 0.475 | 21 |
| INFORM SYST RES | 2.872 | 22 | 1.073 | 22 | 2.647 | 22 | 0.667 | 22 | 0.466 | 22 |
| SCIENTOMETRICS | 2.814 | 24 | 1.016 | 23 | 2.506 | 23 | 0.631 | 23 | 0.441 | 23 |
| RES EVALUAT | 2.847 | 23 | 1.002 | 24 | 2.471 | 24 | 0.623 | 24 | 0.435 | 24 |
| J ASSOC INF SCI TECH | 3.057 | 19 | 0.976 | 25 | 2.408 | 25 | 0.607 | 25 | 0.424 | 25 |
| ETHICS INF TECHNOL | 2.755 | 26 | 0.974 | 26 | 2.401 | 26 | 0.605 | 26 | 0.423 | 26 |
| J INF SCI | 2.409 | 29 | 0.969 | 27 | 2.391 | 27 | 0.602 | 27 | 0.421 | 27 |
| QUAL HEALTH RES | 2.733 | 27 | 0.946 | 28 | 2.334 | 28 | 0.588 | 28 | 0.411 | 28 |
| J MED LIBR ASSOC | 1.989 | 33 | 0.880 | 29 | 2.170 | 29 | 0.547 | 29 | 0.382 | 29 |
| INFORM SOC | 2.140 | 30 | 0.874 | 30 | 2.156 | 30 | 0.543 | 30 | 0.380 | 30 |

## The Disciplinary Difference between the Logarithmic Correction Impact Factor and the Traditional Impact Factor

The JIF across various disciplines is not comparable, primarily due to substantial variations in JIF values among different fields. Consequently, the narrower the range of variation for a given indicator among journals in various disciplines, the more consistent the indicator becomes, resulting in a more effective evaluation of academic journals across diverse fields. To compare the disciplinary differences of each indicator, we calculated the coefficient of variation for nine indicators, such as $IF_{2018}$ (Table 3). It is evident that $IF_{2018}$ has the largest disciplinary difference, followed by $rIF_{2018}$ after disciplinary standardization, and the smallest disciplinary difference is $cnIF_{log1.5}$. The evaluation effect across disciplines of aJIFP and JIPR8 has been confirmed (Liu et al. 2017).

Table 3: Variation of Each Index of 401 journals in 8 Disciplines

| Index | Statistic | | |
|---|---|---|---|
| | Mean value | Standard deviation | Coefficient of variation |
| $IF_{2018}$ | 2.120 | 1.952 | 0.921 |
| aJIFP | 48.909 | 28.078 | 0.574 |
| JIPR8 | 13.200 | 6.873 | 0.521 |
| $IF_{log1.5}$ | 1.920 | 1.099 | 0.572 |
| $IF_{ln}$ | 0.780 | 0.446 | 0.572 |
| $IF_{log5}$ | 0.480 | 0.277 | 0.577 |
| $IF_{log10}$ | 0.340 | 0.194 | 0.571 |
| $rIF_{2018}$ | 0.790 | 0.613 | 0.776 |
| $cnIF_{log1.5}$ | 0.840 | 0.425 | 0.506 |

## The Relationship between the Journal Impact Factor Based on Logarithmic Correction in Eight Disciplines and Other Bibliometric Indicators

The Kolmogorov–Smirnov test results show that $IF_{2018}$, $IF_{log1.5}$, $IF_{ln}$, $IF_{log5}$, $IF_{log10}$, and $rIF_{2018}$ of 401 journals from 8 disciplines do not show a normal distribution, whereas aJIFP, JIPR8, and $cnIF_{log1.5}$ show a normal distribution. Therefore, Spearman correlation analysis is used to test the correlation between $IF_{2018}$, $IF_{log1.5}$, $IF_{ln}$, $IF_{log5}$, $IF_{log10}$, $rIF_{2018}$, and other indexes, whereas Pearson correlation analysis is used to test the correlation between aJIFP, JIPR8, and $cnIF_{log1.5}$. The results are shown in Table 4. The results of the correlation analysis show the following characteristics:

(i) Any two indicators are highly correlated ($r$>0.750);

(ii) The correlation coefficient of any two of the four logarithmic correction impact factors, such as $IF_{log1.5}$, $IF_{ln}$, $IF_{log5}$, and $IF_{log10}$, is 1.000 (100% correlative);

(iii) The largest correlation coefficients with the two confirmed indicators of evaluation across disciplines' aJIFP and JIPR8 are $cnIF_{log1.5}$.

Table 4: Correlations Between Logarithmic Correction Impact Factor and Other Bibliometric Indicators

| Index | aJIFP | JIPR8 | $IF_{log1.5}$ | $IF_{ln}$ | $IF_{log5}$ | $IF_{log10}$ | $rIF_{2018}$ | $cnIF_{log1.5}$ |
|---|---|---|---|---|---|---|---|---|
| $IF_{2018}$ | 0.867 | 0.873 | 0.996 | 0.996 | 0.996 | 0.996 | 0.760 | 0.782 |
| aJIFP | | 0.878 | 0.863 | 0.863 | 0.863 | 0.863 | 0.870 | 0.879 |
| JIPR8 | | | 0.875 | 0.875 | 0.875 | 0.875 | 0.967 | 0.970 |
| $IF_{log1.5}$ | | | | 1.000 | 1.000 | 1.000 | 0.754 | 0.783 |
| $IF_{ln}$ | | | | | 1.000 | 1.000 | 0.754 | 0.783 |
| $IF_{log5}$ | | | | | | 1.000 | 0.754 | 0.783 |
| $IF_{log10}$ | | | | | | | 0.754 | 0.783 |
| $rIF_{2018}$ | | | | | | | | 0.990 |

## The Inter-Group Difference and Intra-Group Variation Degree of Each Index of Journals in Different Partitions

According to the JCR partition of journals, 401 journals are divided into 4 groups: Q1, Q2, Q3, and Q4. The differences in each indicator between groups are shown in Table 5, and the variations within groups are shown in Table 6. Journal partitioning aims to facilitate a straightforward cross-disciplinary assessment. The greater the difference among the four partitions, the better the discrimination of the indicator. In terms of cross-disciplinary evaluation, greater variations in each indicator across the four journal groups yield a more effective evaluation. Within the same partition, where journals are of the same level, smaller differences in indicators signify better consistency.

Therefore, the ideal evaluation indicator across disciplines should be that the differences among the Q1, Q2, Q3, and Q4 groups are evident (the discrimination is high), whereas the variation degree of the indexes in the same group (partition) is relatively small (high consistency degree). Table 5 shows that the *P* is 0 when the different test statistics of each journal's evaluation index inter-group are limited to three decimal places, indicating that the differences of each index inter-group are statistically significant. From the $\chi^2$ value, we can find that the inter-group differences among the aJIFP, $rIF_{2018}$, $cnIF_{log1.5}$, and JIPR8 are the most evident (these four indicators are all discipline-standardized), whereas the differences of other indicators inter-group are relatively insignificant. The inter-group differences in the aJIFP is the most evident possibly because the grouping is based on the journal partition of the JCR, both are of the same origin, and they are all based on the conversion of the JIF; thus, the aJIFP shows ideal differences between groups. If this factor is excluded, the best performance indicator should be $cnIF_{log1.5}$ and JIPR8.

The degree variation of each journal indicator in each partition is presented in Table 6. It can be seen that $cnIF_{log1.5}$ has a small degree of variation in 4 regions, and the coefficient of variation ranks second in ascending order. The degree variation of $IF_{2018}$ is the largest in journals in the Q1, Q2, Q3, and Q4 partitions. Judging from the discrimination of indicators among journals in different partitions and the stability of indicators in the same partition, the performance of $cnIF_{log1.5}$ is also the most ideal.

Table 5: Kruskal–Wallis Test Statistics of Each Index Inter-group.

| Index | $\chi^2$ | *P* |
|---|---|---|
| $IF_{2018}$ | 245.753 | 0.000 |
| aJIFP | 351.335 | 0.000 |
| JIPR8 | 324.570 | 0.000 |
| $IF_{ln}$ | 241.009 | 0.000 |
| $IF_{log1.5}$ | 241.009 | 0.000 |
| $IF_{log5}$ | 241.009 | 0.000 |
| $IF_{log10}$ | 241.009 | 0.000 |
| $rIF_{2018}$ | 316.362 | 0.000 |
| $cnIF_{log1.5}$ | 318.164 | 0.000 |

Table 6: Variation of Each Indicator Intra-group of the Journals in the Four Partitions.

| Index | Q1 journals | | | Q2 journals | | | Q3 journals | | | Q4 journals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean value | SD* | CV** | Mean value | SD* | CV** | Mean value | SD* | CV** | Mean value | SD* | CV** |
| $IF_{2018}$ | 4.260 | 2.444 | 0.574 | 2.180 | 0.982 | 0.450 | 1.440 | 1.105 | 0.767 | 0.670 | 0.436 | 0.651 |
| aJIFP | 84.101 | 10.174 | 0.121 | 61.534 | 10.959 | 0.178 | 37.188 | 9.969 | 0.268 | 13.847 | 8.212 | 0.593 |
| JIPR8 | 22.070 | 4.985 | 0.226 | 14.540 | 2.820 | 0.194 | 10.500 | 3.171 | 0.302 | 5.950 | 2.663 | 0.448 |
| $IF_{ln}$ | 1.280 | 0.395 | 0.309 | 0.860 | 0.280 | 0.326 | 0.630 | 0.270 | 0.429 | 0.350 | 0.196 | 0.560 |
| $IF_{log1.5}$ | 3.150 | 0.975 | 0.310 | 2.120 | 0.691 | 0.326 | 1.570 | 0.665 | 0.424 | 0.870 | 0.483 | 0.555 |
| $IF_{log5}$ | 0.790 | 0.246 | 0.311 | 0.540 | 0.174 | 0.322 | 0.390 | 0.168 | 0.431 | 0.220 | 0.122 | 0.555 |
| $IF_{log10}$ | 0.550 | 0.172 | 0.313 | 0.370 | 0.122 | 0.330 | 0.280 | 0.117 | 0.418 | 0.150 | 0.085 | 0.567 |
| $rIF_{2018}$ | 1.570 | 0.662 | 0.422 | 0.830 | 0.222 | 0.267 | 0.530 | 0.240 | 0.453 | 0.270 | 0.156 | 0.578 |
| $cnIF_{log1.5}$ | 1.380 | 0.294 | 0.213 | 0.940 | 0.187 | 0.199 | 0.680 | 0.183 | 0.269 | 0.390 | 0.180 | 0.462 |

*SD-Standard deviation **CV-Coefficient of variation

## The Selection of Eight Disciplines into the Top 100 Journals Ranked by Different Indicators

The purpose of standardizing journal evaluation indicators across disciplines is to minimize disciplinary variations in these indicators, allowing for their reasonable application in cross-disciplinary evaluations. An ideal cross-disciplinary evaluation indicator should provide journals from all fields with approximately equal opportunities to be recognized as "excellent journals." To verify the evaluation effect across disciplines of the impact factor of the disciplinary standardization established in this study, we calculate the percentage of 8 disciplines selected into the top 100 journals ranked by 4 indicators: $IF_{2018}$, $IF_{log1.5}$, $cnIF_{log1.5}$, and $rIF_{2018}$ (Table 7). As evident in Table 7, ranked by $IF_{2018}$, as many as 17 out of 32 materials science, biomaterials journals entered Top 100 with a selected ratio of 53.1%; merely 3 out of 54 ethics journals (5.6%) entered Top 100; even none of history of social sciences journal are recorded in Top 100. The probability of each discipline being selected as "excellent journals" is significantly different. There is little difference between the probability of $IF_{log1.5}$ and $IF_{2018}$, each with a coefficient of variation greater than 0.700. Compared with $IF_{log1.5}$ and $IF_{2018}$, the selection results based on $cnIF_{log1.5}$ and $rIF_{2018}$ following disciplinary standardization are relatively balanced. Among them, the most balanced index for each discipline selected into the Top 100 journals of the probability is $cnIF_{log1.5}$, with the lowest coefficient of variation i.e. only 0.252.

Table 7: Comparisons of Journals Selected into the Top 100 in 8 Disciplines Ranked by Different Indicators

| Discipline | No. of journals | Numbers of journals selected into Top 100 ranked by different indicators | | | | Rates of journals selected into Top 100 ranked by different indicators | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $IF_{2018}$ | $IF_{log1.5}$ | $cnIF_{log1.5}$ | $rIF_{2018}$ | $IF_{2018}$ | $IF_{log1.5}$ | $cnIF_{log1.5}$ | $rIF_{2018}$ |
| Virology | 36 | 16 | 15 | 9 | 9 | 0.444 | 0.417 | 0.250 | 0.250 |
| Geology | 46 | 6 | 7 | 10 | 9 | 0.130 | 0.152 | 0.217 | 0.196 |
| Engineering, Environmental | 52 | 23 | 23 | 8 | 8 | 0.442 | 0.442 | 0.154 | 0.154 |
| Materials Science, Biomaterials | 32 | 17 | 18 | 7 | 7 | 0.531 | 0.563 | 0.219 | 0.219 |
| Ophthalmology | 59 | 13 | 13 | 17 | 16 | 0.220 | 0.220 | 0.288 | 0.271 |
| Information Sci. & Library Sci. | 88 | 22 | 22 | 26 | 27 | 0.250 | 0.250 | 0.295 | 0.307 |
| Ethics | 54 | 3 | 2 | 11 | 11 | 0.056 | 0.037 | 0.204 | 0.204 |
| History of Social Sciences | 34 | 0 | 0 | 12 | 13 | 0.000 | 0.000 | 0.353 | 0.382 |
| Coefficient of variation of selection rate of top 100 journals in 8 disciplines | | | | | | 0.755 | 0.769 | 0.252 | 0.288 |

## DISCUSSION AND CONCLUSIONS

### (a) Citations of journal papers in a normal distribution after logarithmic transformation

The distribution of paper citations in almost every journal is skewed, as illustrated in Figure 1a. This skewness frequently results in a significant increase in the JIF due to a single paper with exceptionally high citations. For example, the impact factor of *Cancer Journal for Clinicians* in 2012 reached an astonishing 153.459. Remarkably, the two most highly cited papers contributed to 70.9% of its impact factor (Liu 2014). This statistical flaw within the impact factor is a point of frequent criticism by academics. Therefore, citations must undergo normality conversion to construct a reasonable evaluation index of journal influence based on the average citations. This study uses *Geology* (journal) and Materials Science and Biomaterials (discipline) as examples to demonstrate the effectiveness of logarithmic conversion, and Figures 1b-f and 2b-f show that there is minimal difference in the effectiveness of the logarithmic conversion between different bases.

Notably, the larger the logarithm base, the smaller the value after citation conversion, and the smaller the $IF_{log}$ will be. To make the $IF_{log}$ of each journal have good discrimination, it is suggested that citations with smaller logarithm bases be converted as far as possible to ensure the normality conversion effect.

**(b) Impact factor of each discipline's journals in a normal distribution after logarithmic correction**

In general, both the JIF and the total citations within each discipline exhibit skewed distributions (Yu, Yuan, and Wang 2018; Clauset, Shalizi, and Newman 2009). The $IF_{2018}$ of the eight disciplines selected for this study also follows a skewed distribution, similar to the $rIF_{2018}$. However, $IF_{log1.5}$, $IF_{ln}$, $IF_{log5}$, $IF_{log10}$, and $cnIF_{log1.5}$ exhibit a normal distribution. Given the non-normal distribution of most JIFs within each discipline, it is not appropriate to divide the impact factor of each journal by the disciplinary average or median impact factor to conduct disciplinary standardization.

This study found that almost every discipline journal's $IF_{log1.5}$, $IF_{ln}$, $IF_{log5}$, and $IF_{log10}$ were normally distributed. Therefore, it is reasonable to divide the $IF_{log1.5}$ of a certain journal by the $aIF_{log1.5}$ of the discipline to which it belongs to conduct disciplinary standardization. Moreover, the $cnIF_{log1.5}$ of each disciplinary journal is normally distributed.

**(c) $IF_{log}$ with different logarithm bases are equivalent in journal evaluation**

The results show a 100% correlation between any two of the four logarithmic correction impact factors, namely $IF_{log1.5}$, $IF_{ln}$, $IF_{log5}$, and $IF_{log10}$, irrespective of whether they are in the same or different disciplines. In other words, these four indicators demonstrate equivalence in the evaluation of the same or different disciplines. Therefore, in this study disciplinary standardization is soley applied to $IF_{log1.5}$.

**(d) $cnIF_{log1.5}$ is an ideal evaluation indicator for the journals in different disciplines**

From a statistical perspective, the proposal to calculate $IF_{log}$, after converting the citations of papers with skewed distributions into a logarithmic format, aims to rectify the statistical shortcomings of the impact factor. Thus, $IF_{log}$ is standardized by dividing by the disciplinary aggregate impact factor to create $cnIF_{log1.5}$. The indicator design is more scientific and reasonable, and the evaluation effect across disciplines is fully supported by empirical research: (i) among the nine indicators observed, the journals in the eight categories display the least dispersion in terms of $cnIF_{log1.5}$ ($r$=0.506); (ii) highly correlated with the aJIFP and JIPR8, which are two confirmed indicators of evaluation across disciplines; (iii) grouped by the JCR partition, $cnIF_{log1.5}$ showed ideal inter-group discrimination (significant difference between the Q1, Q2, Q3, and Q4 journal's $cnIF_{log1.5}$), and excellent intra-group stability (little difference between journal indicators in the same partition); (iv) $cnIF_{log1.5}$ was used as the evaluation indicator to rank the journals in the eight categories, and the probability entering the top 100 journal was the most homogeneous.

In this study, we addressed the statistical limitations of the impact factor and introduced corrections to create the cnIF. Among the various indicators we examined, $cnIF_{log1.5}$ proved to be particularly effective in evaluating academic journals across different disciplines, both in theoretical analysis and empirical research. Its robust performance makes it a valuable candidate for widespread adoption and application. Additionally, this study is not without its drawbacks: the effect of the standardized approach can only be fulfilled when implemented in a specific disciplinary classification system, a task that can be complicated and highly systematic. There are multiple reference standards for disciplinary classification, and disciplinary classification systems can vary across different countries, regions, or databases. Currently, there is no universally established scientifically reasonable disciplinary classification system in place. However, the appropriate classification of journals into disciplinary categories is a fundamental prerequisite for effective journal evaluation. Given that an increasing number of scholars have been devoted to research and improvement of disciplinary classification, this ongoing effort suggests that future journal evaluations may align with more scientifically sound disciplinary categorization systems.

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## CONFLICT OF INTEREST

The authors declare no conflicts of interest regarding the publication of this paper.

## AUTHOR DECLARATION

We authored the research paper in both English and Chinese during our study. The Chinese-language article has already been published in the *Journal of the China Society for Scientific and Technical Information* in 2021, Volume 40, Issue 2, pages 125-134. We have obtained permission from the *Journal of the China Society for Scientific and Technical Information* to publish this paper in the English. The complete text of the Chinese-language article can be accessed at the following link: https://qbxb.istic.ac.cn/CN/Y2021/V40/I2/125.

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