Research on the Rationality of Half-life Indicator Application in Journal Evaluation: Postprint

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Abstract

[Purpose/Significance] Based on a review of domestic and international research regarding the half-life indicator in journal evaluation, this study identifies instances of confusion and misuse in the application of the half-life indicator and conducts an analysis and discussion of these issues.

[Method/Process] Utilizing indicator data from core journals in library & information science and economics as reported in the "Statistical Analysis Database of International and Domestic Influence of Chinese Academic Journals" as the sample, and employing visualization tools and statistical methods such as correlation analysis, this paper examines the rationality of applying the half-life indicator in journal evaluation.

[Results/Conclusion] The findings indicate that the half-life indicator possesses certain limitations in journal evaluation. Regarding the reflection of literature aging velocity, there exists a substantial discrepancy between diachronic and synchronic measurement approaches. Additionally, certain confusions and misuses persist concerning the application of the half-life indicator. In response to these circumstances, recommendations for the appropriate use of the half-life indicator are proposed.

Full Text

Preamble

Research on the Application Rationality of Half-life Indexes in Periodical Evaluation

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Abstract

[**Purpose/Significance**] Based on a review of domestic and international research on half-life indexes in periodical evaluation, this study identifies issues of mixed and misuse of half-life indexes during their application, and analyzes and discusses these problems. [**Method/Process**] Using index data from core journals in library and information science and economics from the *Statistical Database of International and Domestic Influences in China Academic Journals* as samples, this paper discusses the rationality of applying half-life indexes in periodical evaluation through visualization tools, correlation analysis, and other statistical methods. [**Results/Conclusion**] The findings reveal that half-life has certain limitations in periodical evaluation. There are significant differences between diachronic and synchronic measurement methods in reflecting literature aging rates, and some confusion and misuse exist regarding the application of half-life indexes. This paper proposes recommendations for the appropriate use of half-life indexes in response to these issues.

Keywords: half-life; literature aging; periodical evaluation; rationality

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2 Research Status at Home and Abroad

The half-life index, as a quantitative indicator for studying literature aging, was first proposed by scientist J. D. Bernal in 1958 to characterize the aging speed of literature and information. After 60 years of development, scholars have conducted more in-depth and extensive research on half-life indexes, including expanding the concept of half-life, distinguishing definitions across different dimensions, and applying various half-life indexes to aging research in different disciplines. Additionally, as a literature aging indicator, the relationship between half-life and other aging indicators has been discussed and verified by many scholars. This paper reviews existing domestic and international research to examine the current status of half-life as a periodical evaluation indicator and discusses the rationality of its application in academic journal evaluation.

Academic journal literature was selected as the basis for this review because academic journals, as carriers of knowledge, have stronger timeliness compared to monographs, research reports, and proceedings, and core journals maintain high academic standards and publication quality with certain authority and foresight. This study selected references from CNKI Chinese database and Web of Science foreign database, and combined bibliometric analysis with CiteSpace keyword co-occurrence and visualization tools to present the research status of half-life.

In the CNKI database, the search strategy was: subject contains (half-life) AND

full text contains (literature aging OR periodical aging), retrieving 425 Chinese documents. In the Web of Science database core collection, the advanced search strategy was: (subject contains (obsolescence of literature) OR subject contains (aging of literature)) AND subject contains (half-life), retrieving 330 foreign documents.

2.1 Publication Volume Analysis

Research on half-life in periodical evaluation first appeared in 1970. However, due to database construction and collection period limitations, many early documents were not included, especially since most domestic universities and research institutes can only access WOS documents published after 1990. Therefore, this study analyzed publication volume changes from 1995 to 2015.

As shown in [Figure 1: see original paper], the overall trend of Chinese literature indexed by CNKI shows continuous fluctuation during the 20-year period from 1995-2015, with reduced fluctuation in recent years, indicating scholars' attention to half-life research has stabilized. Foreign literature indexed by WOS grew slowly during 1995-2005, with research on half-life indexes increasing from fewer than 10 to 25 papers, showing rising attention from domestic and international scholars. Both Chinese and foreign literature show an upward trend, suggesting that half-life-related research remains immature with many issues requiring further investigation.

2.2 Thematic Analysis

High-frequency keywords can reflect popular research themes, and keyword co-occurrence can reveal associations between hot topics. Higher co-occurrence frequency indicates richer research. This study imported keywords from the retrieved documents into CiteSpace to display the top 20 Chinese and English keywords by frequency, with results shown in . The first appearance year reflects when a hotspot was earliest proposed, and centrality reflects a keyword's position in the co-occurrence network, with values closer to 1 indicating more central positions.

The comparison of high-frequency keywords from CNKI and WOS in shows both similarities and differences between domestic and international research themes. First, citation analysis ranks highest in Chinese research, followed by bibliometrics, while citation analysis also appears in the top 20 in foreign research, indicating these are the main research methods. Second, regarding half-life, the main research objects include scientific literature and journals, with research contents covering literature aging models, impact factors as aging indicators, and citation counts. Additionally, half-life indexes and Price's index, another literature aging indicator, co-occur frequently, with related research primarily discussing their relationship or using them jointly as periodical aging measurement indicators. Foreign literature also involves more practical applications of half-life, such as in library collection management and applications in market

and management fields.

Comparatively, foreign literature focuses more on research about the concepts and calculations of aging indicators themselves. This study further used high-frequency keyword co-occurrence networks to show relationships between keywords and employed CiteSpace's clustering function to extract research theme hotspots (keywords with the same color represent clusters of related themes).

The keyword co-occurrence clustering map for CNKI documents in [Figure 2: see original paper] reveals four main themes: (1) periodical evaluation research centered on citation analysis and statistical analysis; (2) half-life application research centered on literature weeding; (3) periodical evaluation indicator research centered on impact factors; and (4) literature aging research centered on journals and documents.

The keyword co-occurrence clustering map for WOS documents in [Figure 3: see original paper] shows four main themes: (1) influence evaluation research centered on citation analysis/impact; (2) scientific literature aging research centered on obsolescence/scientific literature; (3) practical application research centered on planned obsolescence/innovation; and (4) medical research centered on pharmacokinetics/children.

These clustering results reveal that half-life indexes in citation analysis and periodical evaluation occupy important positions in both Chinese and foreign literature, making them one of the commonly used indicators in citation analysis for periodical evaluation. The second focus is specific application research of half-life indexes, primarily in libraries and medical fields. However, since the proposal of half-life indexes, significant disagreements have persisted regarding their meaning and calculation methods. This raises questions about the rationality of using half-life in periodical evaluation and various practical application fields, and whether current usage research has problems. Therefore, this paper summarizes domestic and international research on the meaning, calculation methods, and selection of half-life indexes in periodical evaluation based on the 755 retrieved documents.

(1) Selection of Half-life Indexes in Periodical Evaluation. Eighty percent of studies select citation half-life and cited half-life calculated using synchronic methods when evaluating journals, while diachronic half-life is less commonly used. Two main reasons explain this preference: First, synchronic half-life is convenient to calculate, with major databases (such as CNKI and JCR) providing half-life indexes calculated based on their collections and publishing them in annual reports for easy download and retrieval. Second, synchronic half-life indexes have richer meanings: besides generally reflecting journal aging speed, cited half-life also reflects publication quality, while citation half-life reflects the timeliness of cited references and attention to recent research findings. In contrast, diachronic half-life primarily characterizes the decay speed of journal literature value with a more singular meaning.

(2) Calculation Methods for Half-life Indexes in Periodical Evalua-

tion. Scholars have continuously innovated and verified calculation methods for half-life over the years. Currently, the widely accepted and used half-life indexes are citation half-life and cited half-life calculated from synchronic perspectives, and diachronic half-life calculated from diachronic perspectives. For synchronic half-life, three main calculation methods exist: graphical method (finding the publication year corresponding to half of cumulative citations based on citation distribution), interpolation method (finding the year closest to 50% of cumulative citation percentage and calculating the interval from the statistical year), and formula method (based on the classic B-K equation for literature aging or Motylev's revision, though scholars have derived many formulas with varying applicability). For diachronic half-life, two main calculation approaches exist: (1) using literature aging models to calculate half-life through formulas, such as Brooks' cumulative exponential model; and (2) predicting future development of literature indicators based on grey first-order linear equation prediction theory to calculate half-life, both of which have gained some recognition.

(3) Meaning of Half-life Indexes in Periodical Evaluation. Numerous studies compare changes and differences in half-life indexes through bibliometrics and citation analysis to evaluate and discuss discipline or journal life cycles, development speeds, and the timeliness of literature utilization and research vitality. In summary, half-life indexes play an important role in periodical evaluation, but their calculation is influenced by multiple factors, such as annual publication volume fluctuations and discipline characteristics, which affect the rationality of horizontal comparisons. Additionally, changes in research focus and hotspots influence journal citation patterns. However, most studies using half-life indexes for periodical evaluation fail to consider these influencing factors' impact on evaluation results, and unreasonable interpretations exist, confusing synchronic and diachronic half-life concepts. Therefore, this paper conducts comparative research between half-life indexes and journal influence evaluation indicators based on actual statistical data, and deeply analyzes half-life concepts to discuss the rationality of applying half-life indexes in academic journal evaluation.

3 Empirical Analysis

Currently, journal quality evaluation primarily uses influence evaluation indicators such as total citation frequency, Journal Impact Factor (JIF), and immediacy index based on citation counts. This paper compares and analyzes journal influence evaluation indicators with half-life indexes to verify the validity and applicability of half-life indexes in journal quality evaluation. If they lack validity for quality evaluation, what significance do half-life indexes have as periodical evaluation indicators?

3.1 Data Sources and Calculation Methods

Empirical data were obtained from the *Statistical Database of International and Domestic Influences in China Academic Journals* (URL: http://cjcr.cnki.net),

which publishes international and domestic evaluation indicators for nearly 6,000 officially published Chinese academic journals, objectively reflecting their domestic influence and publication quality. This study selected 11 core journals in library and information science (L_1 to L_{11}) and 8 core journals in economics (E_{11} to E_{19}) from this database, extracting their 2015 indicator data, including core evaluation indicators reflecting academic journal influence (total citation frequency, JIF, immediacy index) and half-life indexes reflecting literature aging (citation half-life and cited half-life). Diachronic half-life was not included in the database, so it was calculated independently using formulas and citation data. Data collection was completed in April 2017.

3.1.1 Journal Influence Indicator Data The journal influence indicators and calculation methods provided in the *Statistical Database of International and Domestic Influences in China Academic Journals* are shown in .

3.1.2 Half-life Indicator Data Among half-life indicators, synchronic-based cited half-life and citation half-life were extracted from the database using the calculation methods shown in . Diachronic half-life was calculated independently since the database did not include it.

Diachronic half-life views literature aging as a gradual process. After publication, it tracks citation frequency changes and decay patterns, with the time when cumulative citations reach 50% of total citations defined as the diachronic half-life. However, since future utilization is difficult to predict, this method has been continuously discussed by scholars, and no universally accepted calculation method has emerged to date. Diachronic half-life was first proposed by B. C. Brooks in 1970, who noted from a diachronic perspective that scientific journal literature citations decay over time, conforming to the negative exponential model proposed by J. D. Bernal. In 1971, he proposed the literature aging cumulative exponential model: Y(t) = Mbt, from which literature aging half-life can be calculated. Subsequent scholars' extensive empirical research has confirmed the rationality of this model in reflecting literature aging.

This study selected the classic aging model B. C. Brooks cumulative exponential model accepted by most scholars:

Y(t) = Ce^(-at) (1)

In formula (1), Y(t) represents cumulative citation frequency for literature published t years ago, C is a discipline-dependent constant, a is the aging rate, and t represents citation age. The cumulative exponential model is an exponential equation that can be transformed into a univariate linear equation by taking logarithms of both sides:

ln Y(t) = ln C - at (2)

Let A = ln C and B = -a, then y = ln Y(t), x = t (5)

Based on existing actual data, equation coefficients A and B were calculated using the least squares method, from which aging rate a and half-life T were derived. During calculation, we found that first-year data deviated significantly, reducing model fitting accuracy, which is related to the fact that first-year statistics start from publication time. Therefore, first-year data were excluded from calculations.

Analysis of variance was used to test the significance of the regression equation. Model P-values were all less than 0.001, showing significant differences, and R^2 values were all greater than 85%, indicating strong explanatory power.

3.1.3 Statistical Description of Indicators After data processing, 6 evaluation indicators (H_1 to H_6) for 19 core journals (L_1 to L_{11} and E_{11} to E_{19}) were obtained, with results shown in and .

Based on statistical results and descriptive analysis, several findings emerged: (1) The total citation frequency indicator H_1 shows significant differences across 19 core journals, with a large standard deviation—the maximum value is nearly 35 times the minimum, with most journal means around 2,000. Analysis reveals that total citation frequency has an important relationship with journal scale and publication volume, and horizontal comparison under the same publication volume can reflect journal influence. (2) For composite impact factor indicator H_2, library and information science journals remain stable around 1.5 with little variation, while economics journals show more obvious differences. Analysis shows that impact factor reflects a publication's paper influence over the past two years, but is seriously affected by publication lag, publication volume, and discipline differences, making it largely non-comparable horizontally. (3) Citation half-life H_4 and cited half-life H_5 have similar descriptive statistics with close means, standard deviations, skewness, and kurtosis. They differ from diachronic half-life H_6, which shows little variation across 19 journals with values around 3 years. Library and information science journals (L_1 to L_{11}) have relatively close half-life values with small standard deviations, all within 5 years, while economics journals show greater variation in half-life indicators, with cited half-life and citation half-life values much larger than diachronic half-life.

3.2 Correlation Analysis Between Half-life and Journal Citation Indicators

Correlation tests revealed that H_1, H_2, and H_3 (total citation frequency, JIF, and immediacy index) have significant strong correlations at the 0.01 level, with correlation coefficients above 0.7, demonstrating data validity. For H_4 and H_5, citation half-life and cited half-life show high positive correlation at the 0.01 level, with a correlation coefficient of 0.939, consistent with previous research findings. Diachronic half-life indicator H_6 shows generally negative correlations with the other five indicators, with moderate negative correlations with cited half-life and citation half-life at the 0.05 level, with coefficients of

-0.542 and -0.457. Influence indicators H_1, H_2, and H_3 do not show significant correlations with half-life indicators H_4, H_5, and H_6.

4 Discussion

4.1 No Correlation Between Influence Indicators and Literature Aging Half-life Indicators

Influence indicators primarily characterize journal influence in academia through publication volume and citation frequency, with higher citation frequency indicating greater article influence and largely reflecting journal academic quality. Half-life indicators reflect journal aging speed—citation half-life reflects the novelty degree of publications' used literature and has a strong relationship with discipline characteristics. In disciplines with rapid knowledge updates, authors focus more on recent research findings and tend to cite recently published articles, resulting in smaller citation half-life values, such as *Library and Information Science* (L_1) with a citation half-life of 2.7 years. Cited half-life reflects the continued use of previously published literature by scholars; a long cited half-life indicates more classic papers or fewer recent citations, such as *Studies in Chinese Social and Economic History* (E_{19}) with a cited half-life of 14 years. Diachronic half-life reflects the aging speed of journal value, which has an important relationship with article content characteristics. In fields with rapid knowledge updates, diachronic half-life is small (e.g., economics), while in fields with profound theoretical foundations, diachronic half-life is relatively long (e.g., history and political science). Therefore, influence evaluation indicators and literature aging indicators measure different content with different connotations. Journal academic quality has no direct relationship with aging speed—journals with greater influence may have smaller half-life values, such as *Economic Dynamics* (E_{14}), while higher-quality journals may have larger half-life values, such as *Research in Chinese Economic History* (E_{18}) and *Studies in Chinese Social and Economic History* (E_{19}). Thus, half-life indicators should not be directly used as indicators to evaluate journal quality; unlike influence indicators, half-life indicators are influenced by more factors and require more targeted interpretation.

4.2 High Positive Correlation Between Citation Half-life and Cited Half-life

Journal citation half-life measures the timeliness of references cited by a journal, representing a quantitative indicator of how interested the citing journal is in references published within a recent timeframe. A short citation half-life means the journal requires references with a shorter time span, while a long citation half-life indicates a longer required time span. This has a strong relationship with discipline characteristics. For disciplines with rapid knowledge updates, citing recent articles indicates authors pay more attention to latest research findings and can be inferred to be more innovative and progressive. In disciplines

that value classic theoretical foundations, naturally more older references are cited.

Cited half-life reflects the continued use of previously published literature by scholars. On one hand, a long cited half-life indicates long literature lifespan, many long-effective papers, and numerous classic achievements, symbolizing good journal quality. On the other hand, it may also indicate relatively fewer citations for recent papers compared to earlier ones, suggesting a possible decline in recent paper quality. Therefore, a longer cited half-life must be accompanied by non-decreasing citation frequency to reflect the journal's long-term quality characteristics. Both indicators are discipline-specific. When journals belong to disciplines with rapid knowledge updates, they cite recent references more frequently, resulting in smaller citation half-life values. Simultaneously, newer previously published literature receives many citations, leading to smaller cited half-life values. Clearly, citation half-life and cited half-life reflect two expressions of the same phenomenon, thus having significant correlation, consistent with our empirical verification showing a Spearman correlation coefficient of 0.939 between citation half-life (H_4) and cited half-life (H_5).

4.3 Negative Correlation Between Synchronic and Diachronic Half-life

Based on actual data, diachronic half-life (H_6) shows significant negative correlation with cited half-life (H_4) and citation half-life (H_5) at the 0.05 level, with correlation coefficients of -0.542 and -0.457. Half-life is used to characterize literature aging speed. J. D. Bernal proposed a negative exponential model reflecting literature aging, which intuitively expresses the literature aging process and basically conforms to actual observations. However, throughout the entire time domain of literature exchange activities, literature utilization does not follow exponential function patterns at every stage, and the formula cannot reflect the relationship between literature aging factors and aging, thus having certain limitations. In 1960, American librarians R. E. Burton and R. W. Kebler responded to J. D. Bernal's suggestion by analogizing the decreasing use of scientific and technical literature to the natural decay of radioactive elements. After collecting citation data from journals in nine disciplines including mathematics, chemistry, and physics, they found the curves described by this data matched the negative exponential curve of U235 decay. Using graphical methods, they determined half-life for these disciplines and proposed the concept of literature half-life, defined as the time period within which the newer half of all currently utilized literature in a discipline (specialty) was published. This definition is also called "median citation age," and they derived the B-K equation for calculating scientific literature aging half-life. This is based on synchronic observation, which reflects literature aging from a state perspective. E. R. Stinson and F. W. Lancaster confirmed the rationality of synchronic methods. However, some scholars envisioned another method tracking literature utilization after publication over time to study aging patterns, called the diachronic

method. Diachronic methods study literature aging from a process perspective, considering literature aging as a process, which aligns with the definition of literature aging.

Therefore, based on the conceptual origins of the two half-life types, synchronic half-life starts from the state at a research time point, measuring occurred citation situations and measuring journal value decay through citation occurrence times. However, this calculation method has limitations in accurately expressing literature or journal aging. First, its measurement objects (utilized literature) are uncertain, determining half-life values only through comparison of citation frequencies between older and younger literature sets. Second, the literature set published by journals is editor-screened, making it unreasonable to use screened literature citation situations to represent entire discipline development. Synchronic half-life can only reflect journal novelty in citing literature rather than literature aging speed, and it is journal-specific rather than representing entire discipline development. In contrast, diachronic half-life was proposed from the literature aging concept itself and can reflect the value decay process of literature or journals.

5 Conclusion

Currently, some unreasonable usage situations persist in domestic and international research using half-life indexes for periodical evaluation. Some studies use citation analysis methods to treat synchronic half-life as an indicator measuring journal aging speed, which is unscientific. Synchronic half-life reflects journal novelty in literature use, while diachronic half-life reflects literature or journal aging speed. Some research uses synchronic half-life indicators alongside other periodical evaluation indicators as methods to measure journal quality, which is also unreasonable. Synchronic half-life has obvious discipline differences and lacks horizontal comparability. Therefore, when using half-life indicators for periodical evaluation, scholars should first fully understand the conceptual differences between synchronic and diachronic half-life, use them in appropriate contexts, and conduct multi-angle, in-depth interpretations.

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Note: Figure translations are in progress. See original paper for figures.