Analysis of Evolving Trends in Citation Behavior and Their Impact on Citation-Based Evaluation (Postprint)

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Abstract

[Purpose/Significance] Through an analysis of the evolution of author citation behavior over 60 years, this study aims to understand the limitations of citation-based evaluation and promote the development and improvement of academic paper evaluation methods. [Method/Process] By identifying, assessing, and statistically analyzing 3,314 references and 5,222 citations from 280 papers in representative journals of physics and philosophy spanning 1957–2017, we examine citation characteristics across different decades and discuss the potential impact of evolving citation behavior on citation-based evaluation. [Results/Conclusions] The investigation reveals the following conclusions: First, while journal papers show no significant change in reference carrier types and temporal distribution, clear trends exist in average references per paper, average in-text citation frequency of references, citation identity, and citation depth. Second, changes in citation behavior call into question the use of citation analysis as a basis for academic paper evaluation. The increase in average references per paper and the decline in the proportion of deep citations and negative citations weaken the reliability of citation-based evaluation.

Full Text

The Trend of Citation Behavior and Its Impact on Citation Evaluation

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Abstract

[**Purpose/Significance**] This study analyzes the evolution of author citation behavior over six decades to understand the limitations of citation-based evaluation and promote the development and improvement of academic paper evaluation methods. [**Method/Process**] Through identification, judgment, and statistical analysis of citation characteristics across different time periods, we examined 3,314 references and 5,222 citations from 280 papers published in representative physics and philosophy journals between 1957 and 2017, discussing the evolution trends of citation behavior and their potential impact on citation evaluation. [**Results/Conclusions**] The investigation reveals two key findings: First, while there are no significant changes in reference media types and temporal distribution, clear evolutionary trends exist in the average number of references per paper, average in-text citation frequency per reference, citation identification, and citation depth. Second, these changes in citation behavior challenge the validity of citation analysis as a basis for academic paper evaluation. The growth in references per article and the declining proportion of deep and negative citations weaken the reference value of citation evaluation.

Keywords: citation behavior; citation identification; citation depth; citation evaluation; evolution trend; impact analysis
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Introduction

In the architecture of scientific literature, no document exists in isolation; their interconnections are prominently manifested through mutual citations, forming an interrelated network of documents. As direct reflections of author citation behavior and objective outcomes, references and in-text citation content have long served as important foundations for citation-based academic evaluation. However, authors' motivations and purposes for citing vary, and different types of citations contribute differently to the literature. Scholars have classified SCI citation functions into five levels and ten categories: (1) Very unimportant (background, facts); (2) Unimportant (extended reading); (3) General (concepts, definitions); (4) Important (views, conclusions, data); and (5) Very important (methods, related research). Since SCI only provides document-level citations rather than content-level citations, it is difficult to verify citation authenticity from citation indexes, inevitably leading to defects such as false and ceremonial citations.

Currently, citation analysis has formed two primary methods in academic evaluation: evaluation based on citation frequency and evaluation based on citation content. Both are essentially applications and developments of bibliometrics in academic paper evaluation, with metrics primarily based on bibliographic citation data. Research on content-based academic evaluation actually began after Garfield established citation databases, but most studies remained theoretical

discussions or small-scale manual investigations. The academic community has recognized that paper evaluation requires distinguishing different citation types, with citation identification and citation depth being particularly crucial, though research in these areas remains limited and specific evaluation indicators have not yet been formed.

In recent years, the emergence of XML-format structured full-text databases has enabled scholars to use technical means to extract, identify, and count different citation data. As content-based paper evaluation has become more feasible, scholars have begun to reconsider the essence of citation analysis and its potential impact on citation evaluation standards. Ju Xiufang et al. argue that some journals manipulate citations to pursue ranking, affecting the quality of citation data and the reliability of citation-based research. M.V. Wouters suggests that citation evaluation criteria, driven by interests, act like "switchmen" determining the direction of academic achievements, studying changes in paper title length, author count, abstract sentence numbers, and reference numbers under the influence of journal impact factors. Liang Chunyang, when investigating basic types and distribution characteristics of citations in *Philosophical Research*, found that refutation citations—citations used to criticize and negate others' theories—decreased from 35.6% to 4.6% over 30 years. These studies demonstrate changes in author citation behavior and their impact on citation evaluation, but none have deeply explored the patterns of citation behavior change and their specific effects on citation evaluation.

Over the past 60 years, with social, economic, and cultural development, particularly the rapid advancement of science, technology, and network environments, the annual number of published papers, their length, and reference counts have all changed. There is an urgent need for rapid scientific methods to evaluate papers and reduce the time and difficulty of selection. Academic evaluation based on journal impact factors or citation frequency is simple and practical but has generated many negative social phenomena, attracting widespread attention. These issues have also drawn academic attention, with scholars from different disciplines studying factors affecting evaluation results and how to optimize evaluation theories and methods.

Theoretically, citations only indicate authors' attention to cited literature; only substantive content citations or comments demonstrate authors' identification with cited literature. However, both references and citations are forms of citation behavior in scientific research and paper writing, representing attitudes toward cited literature (identification or negation) and serving as important bases for judging cited papers' value and a crucial element of academic paper evaluation. What changes have occurred in references and citations over the years? What proportion of citations are substantive? How has this changed over time? Should evaluation be based on citation frequency or citation content? What proportion of different types of citation identification exist in a paper? These are the questions this study aims to address. In short, we investigate changes in author citation behavior over 60 years, analyze their evolution

patterns and influencing factors, particularly their impact on paper evaluation, to promote the standardized development of academic citations and provide references for citation-based evaluation theory research.

Data Acquisition and Processing

Sample Selection

(1) Sample Disciplines and Time Range. As an exploratory study without comprehensive data collection, we determined an empirical data scope focusing on journal papers. Considering disciplinary diversity, journal establishment time, and operability, we selected *Acta Physica Sinica* for physics and *Philosophical Research* for philosophy between 1957 and 2017, with 10-year intervals. Due to historical reasons, most data from the 1960s and 1970s are missing; when unavailable, we selected appropriate adjacent years as substitutes.

(2) Data Sources and Sampling. We retrieved and downloaded full texts from the CNKI journal database, cross-checking results with journal tables of contents to remove letters to the editor, journal introductions, editorial discussions, correspondence, meeting minutes, announcements, congratulatory messages, reviews, etc. We assigned numbers to papers from each journal and year, using Python's `random.sample(range(1, x), 20)` to select 20 papers per year (where x represents the total number of cleaned papers for that journal in that year). Since this study focuses on the objective results of author citation behavior—namely references and in-text citation content—our investigation included both formal characteristics (reference count, media type, publication year) and content characteristics (citation identification and citation depth), based on data availability.

Definition of Key Concepts

This paper involves concepts including citation behavior, citation analysis, citation evaluation, citation identification, and citation depth. While some concepts have clear meanings, others lack unified definitions in domestic and international research and exhibit overlap. We provide definitions for several important concepts:

(1) Citation Behavior refers to the external manifestation of authors in citation activities under various internal and external factors. In this paper, it specifically refers to the results of author citation: references and in-text citation content.

(2) Citation Content refers to the textual content that characterizes citing literature's reference to cited literature, i.e., sentences containing citation labels or numbers in the main text and their context.

(3) Citation Identification is the emotional tendency (positive, negative, or neutral) when citing literature references cited literature. We categorize "citation identification" into positive citation, neutral citation, and negative citation.

Negative citation includes both negotiated negative citation and negational negative citation. Specifically: (1) Positive citation expresses affirmation, agreement, or value recognition of cited literature; (2) Neutral citation expresses neither agreement nor opposition, with no explicit recognition or criticism; (3) Negotiated negative citation discusses cited literature in a deliberative tone and attitude; and (4) Negational negative citation expresses opposition or points out errors in cited literature. It should be noted that negative citation does not equal actual "error" but represents the citing author's attitude toward cited literature. Examples are shown in .

(4) Citation Depth reveals the knowledge utilization and absorption degree of citing literature, examining the linguistic statement degree and utility level of cited literature content to citing literature as an informetrics indicator. It distinguishes the importance of cited literature to citing literature through shallow citation, medium citation, and deep citation. Definitions are as follows: (1) Shallow citation occurs when authors cite for narrative or decorative purposes or when citing others' references, largely remaining at topic summarization or mention and not essential to the article; (2) Medium citation occurs for research and argumentation needs, where citing literature objectively and clearly discusses cited literature content or applies its data, methods, or theories without making deductions, expansions, or innovations; and (3) Deep citation occurs for research innovation needs, typically citing literature that is enlightening to the research or supportive of its value, holding extreme importance to citing literature. Examples are shown in .

Data Processing

(1) Data Processing Rules. To ensure consistency and validity in data statistics and analysis, we adopted the following rules: (1) We used manual indexing to identify citation identification and citation depth because existing citation type analysis platforms are experimental with limited coverage and not publicly accessible, and because citation identification and depth require semantic-level analysis where manual judgment is more accurate. To reduce subjective influence, we employed multiple cross-validation. (2) For papers citing the same reference multiple times, we calculated reference counts following CSSCI indexing rules—counting each source document only once regardless of citation frequency. However, we treated citation identification and depth separately: if a paper positively cited one view of a reference while negatively citing another, we counted it as one positive and one negative citation, with citation depth calculated similarly. (3) Different disciplines and eras used different reference formats. Considering that footnotes, endnotes, and in-text notes all represent author citations and provide important reference value for citation identification and depth, we treated them all as references for investigation. (4) For references listed only at the end or bottom of pages without specific in-text markers, we included them in reference counts but excluded them from citation identification and depth analysis. (5) When end references used a single marker for multiple

references, we calculated based on actual reference numbers, investigating each reference individually.

(2) Data Processing Results. We investigated 280 papers published in *Acta Physica Sinica* and *Philosophical Research* between 1957 and 2017. Based on PDF full texts downloaded from CNKI, these 280 journal papers contained 3,314 references with 5,222 in-text citations. Details are shown in .

Analysis of Evolution in Citation Form Features

Evolution of Average References per Paper

The average number of references per paper refers to the mean number of references cited per article, calculated as the total references divided by total papers for a given year. Our investigation of *Acta Physica Sinica* and *Philosophical Research* shows that between 1957 and 2017, the average references per paper in both physics and philosophy journals exhibited an overall upward trend. The change was not significant between 1957 and 1977, but the upward trend became clearer after the 1970s. After the 1990s, the growth accelerated: compared to 1997, the average references per paper in physics and philosophy increased by 127% and 76% respectively by 2017. We attribute this primarily to changes in literature access methods, especially the popularization of computers and the internet after the 1990s. The decreasing difficulty of access and exponential growth in literature quantity have increased the number of citable references, thus raising the average references per paper. Results are shown in [Figure 1: see original paper].

Evolution of Average In-text Citation Frequency

Average in-text citation frequency refers to how many times each reference is cited within the main text, calculated as total in-text citations divided by total references for a given year. As shown in [Figure 2: see original paper], between 1957 and 2017, physics papers showed an overall decline in average in-text citation frequency per reference, while philosophy papers fluctuated between 1.53 and 2.38 times without a clear trend. Philosophy consistently maintained higher average in-text citation frequency than physics, likely due to philosophy's speculative nature, where the same references are often cited and discussed repeatedly, combined with lower and slower-growing average references per paper. This prevented a clear trend and kept philosophy's average above physics.

Evolution of Reference Media Types

Reference media types in *Acta Physica Sinica* mainly include journal articles, books, conference papers, dissertations, reports, and standards. *Philosophical Research* additionally includes compiled documents, newspaper articles, speeches, letters, and inscriptions. Overall, books and journal articles dominate both journals, though their proportions differ significantly. Over time, the

combined proportion of journal articles and books remained around 90% in both journals, as shown in [Figure 3: see original paper] and [Figure 4: see original paper].

Evolution of Reference Age Distribution

Our sample of *Acta Physica Sinica* papers contained 2,241 references, with 2,155 having identifiable publication years (86 unknown). *Philosophical Research* papers contained 1,073 references, with 1,010 usable (63 unknown). As shown in [Figure 5: see original paper] and [Figure 6: see original paper], reference age distribution remained relatively consistent without obvious trends. *Acta Physica Sinica* papers primarily cited recent literature: 45.02% of references were published within the previous five years, and 69.70% within ten years. *Philosophical Research* papers tended to cite literature from the previous ten years and before 1912, with these categories comprising 56.57% of all references.

Analysis of Evolution in Citation Content Features

Evolution of Citation Identification

Based on our definition of citation identification, we statistically analyzed citation patterns across different eras, as shown in .

(1) Evolution in *Acta Physica Sinica*. [Figure 7: see original paper] shows that between 1957 and 2017, positive citations in physics increased by approximately 30%. Neutral citations alternately declined and rose, but declines exceeded increases. Negative citations (except in 1977) consistently decreased, dropping approximately 94% over 60 years. Overall, positive citations increased while neutral and negative citations decreased. We attribute this to four factors: (1) Standardization of writing—early physics papers provided brief development histories and parallel research introductions, gradually forming a mature, consistent writing model where literature reviews occupy substantial space, increasing citations expressing respect and acknowledgment; (2) Influence of citation evaluation standards—scholars tend to cite more decorative references with positive attitudes; (3) Development of interdisciplinary research—accelerated by knowledge growth, convenient information exchange, and increasingly open scientific communities, physics citations of other disciplines are predominantly positive; (4) Changes in research question formulation—early papers often based questions on deep analysis of few references, while recent papers list numerous references before identifying gaps, reducing negative citations.

(2) Evolution in *Philosophical Research*. [Figure 8: see original paper] shows that between 1957 and 2017, positive citations in philosophy fluctuated between 60-80% without clear trends. Neutral citations rose from 10.59% in 1957 to 25.69% in 2017, showing an overall upward trend especially before the 1980s. Negative citations decreased from 26.69% in 1957 to 8.40% in 2017, with a brief but significant rebound in the 1980s. Overall, positive citations showed

no clear trend, neutral citations increased, and negative citations decreased. We attribute this to three factors: (1) Social background influence—intellectual debates often emerge in unstable eras or during regime changes, while stable periods see mainstream thought strengthen, making negative citations more common before the 1980s; (2) Changes in expression—early philosophy articles had clear, sometimes intense positions, while recent writing is more cautious and indirect, sometimes obscuring emotional 倾向; (3) Changes in research formulation—shifting from critiquing others' views to listing them before direct exposition, reducing negative citations, though philosophy's inherent speculative nature maintains some negative citation proportion.

Evolution of Citation Depth

Based on our definition of citation depth, we statistically analyzed citation depth across different eras, as shown in .

(1) Evolution in *Acta Physica Sinica*. [Figure 9: see original paper] shows that between 1957 and 2017, shallow citations in physics increased from 28.37% to 61.67% (approximately 117% growth), while deep citations decreased from 38.48% to 8.25% (approximately 79% decline). Medium citations fluctuated around 30%. Overall, shallow citations increased, deep citations decreased, and medium citations showed no clear trend. We attribute this to four factors: (1) Growth in average references per paper—since the number of highly valuable references is limited for any paper, deep citation proportions decline; (2) Writing standardization—physics papers' background and review sections have expanded, but contain mostly summary and narrative citations of low importance; (3) Influence of citation evaluation—many references cited for decorative purposes have little research value; (4) Changes in research formulation—early papers derived research questions from analyzing few references, while recent papers identify gaps after listing numerous references, making early references more important as problem sources and research foundations.

(2) Evolution in *Philosophical Research*. [Figure 10: see original paper] shows that before the 1980s, shallow citations in philosophy hovered around 20% without clear trends, but increased significantly afterward. Medium citations showed an overall declining trend (approximately 25% decrease). Deep citations showed no clear trend before the 1980s but declined significantly afterward. Overall, shallow citations increased while medium and deep citations decreased. We attribute this to two factors: (1) Increased average references per paper in philosophy journals, but limited highly valuable references, reducing deep citation proportions; (2) Changes in research formulation and argumentation—shifting from deeply analyzing others' views to identify research questions to listing views before direct exposition, reducing inheritance-based citations.

Impact of Citation Behavior Evolution on Citation Evaluation

Bibliometrics, based on citations, derives from and results from the basic functions of citations. Therefore, changes in citation behavior inevitably affect citation evaluation. Based on our 60-year investigation, we identify several potential impacts.

Changing Citation Behavior Raises Questions About the Reliability of Citation Evaluation

Neither the citation system nor citation analysis methods were originally created for academic evaluation. While using citations for indexing only affects retrieval efficiency, using them for evaluation influences not only retrieval but also authors' selection of references and citation methods, thereby affecting citation motivations and behavior.

The reliability of citation analysis as an evaluation method presupposes research objectivity and citation necessity. Our investigation reveals clear evolutionary trends over 60 years in reference count, average citation frequency, citation identification, and citation depth—all closely related to citation evaluation. On one hand, the complexity of citation motivations prevents eliminating adverse citation behavior's negative impact; on the other hand, declining citation depth indicates reduced relevance between citing and cited literature, or decreased citation necessity. Therefore, changes in citation behavior question the reliability of citation frequency as an evaluation basis, affecting the scientific nature of citation evaluation.

Growth in References per Paper and Decline in Average Citation Frequency Reduce Reference Value of Citation Data

Scientific research is characterized by historical continuity and inheritance. The growth in average references per paper and decline in average citation frequency have led to an overall increase in citation quantity, weakening evaluation reference value. Larivière et al. (2008) demonstrated that most papers are cited at least once within two to five years after publication, and the proportion of uncited papers published between 1981-2004 has decreased. From an evaluation perspective, increased citation probability means rising absolute citation data volume, while declining average citation frequency indicates reduced relevance between citing and cited literature, meaning the proportion of substantive citations with real evaluative value is decreasing. Therefore, the growth in references per article and decline in citation frequency reduce the reference value of citation data.

Increasing Proportion of Shallow Citations Diminishes Effectiveness of Citation Evaluation

Due to citation content analysis's context dependency, the idea of distinguishing citation types emerged in the 1960s-70s, but experimental research only appeared recently. However, from a cost-effectiveness perspective, shallow citations in physics and philosophy journal papers increased from 28.37% and 18.64% in 1957 to 61.67% and 55.41% in 2017, respectively, exceeding 50% in both fields. Consequently, the distinction between content-based and quantity-based citation evaluation is decreasing, and the effectiveness of qualitative content-based evaluation is diminishing.

Moreover, whether quantitative bibliometric evaluation or qualitative content-based evaluation, both assess papers years after publication or citation occurrence, remaining indirect indicators and evaluations that cannot overcome evaluation lag. As new ideas and methods for real-time content-based evaluation (such as knowledge units) continue to emerge, citation evaluation is no longer the primary choice for academic evaluation.

Declining Proportion of Negative Citations Reduces Reliability of Qualitative Evaluation Based on Citation Content

Academic critique is an important aspect of academic evaluation, and negative citations represent concrete manifestations of peer academic criticism. Whether peer review or citation evaluation, both essentially obtain affirmation of evaluated papers' value through peer identification. However, academic identification is not simple citation and approval but a dialectical unity of approval and critique. Over 60 years, the proportion of negative citation identification has rapidly declined, with *Acta Physica Sinica*'s negative citations approaching zero, clearly deviating from scientific citation patterns. Therefore, the reliability of content-based academic evaluation will also be questioned.

Conclusion

This study analyzed the evolution of author citation behavior in philosophy and physics over 60 years from both formal and content perspectives. Due to changes in social, cultural, network, and academic environments, while reference media types and temporal distribution showed no clear patterns, significant trends emerged in references per paper, average in-text citation frequency, citation identification, and citation depth. Based on this analysis, we examined how citation behavior changes affect citation evaluation, providing references for citation-based evaluation theory. Due to incomplete and non-standard early data and limitations of natural language processing technology, we used manual indexing to identify citation identification and depth. While this may introduce subjective bias and low processing efficiency with small sample sizes, limiting generalizability to other disciplines or document types, our findings provide a foundation for future research.

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Author Contributions

Suo Chuanjun: Responsible for topic selection, framework construction, and guiding paper writing.

Wang Xueyan: Responsible for data collection and analysis, and initial draft writing.

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