Postprint: Characteristics and Influencing Factors of Papers with Sustained Citation Growth

Authors: He Jiejun, Min Chao

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Abstract

[Purpose/Significance] By analyzing the manifestation characteristics and underlying causes of papers with continuously growing citations, this study aims to reveal the patterns associated with sustained academic impact. [Method/Process] Utilizing the American Physical Society (APS) dataset as the data source, papers with sustained citation growth were identified through the BASS model, and papers with non-sustained citation growth were selected as a control group based on the 1:1 principle to compare differences in bibliographic features and citation diffusion networks between the two groups. [Results/Conclusion] The findings demonstrate that papers with sustained citation growth exhibit distinctive bibliographic features and diffusion characteristics: they tend to have longer titles, single-author and two-author collaborations are more prevalent, and they show lower dependence on prior research; such papers possess more modular structures within their citation cascade networks and display a "broadcast-style" diffusion pattern across shorter generational distances.

Full Text

Research on the Features and Influencing Factors of Papers with Continuous Citation Growth

He Jiejun, Min Chao
School of Information Management, Nanjing University, Nanjing 210023

Abstract:
[Purpose/Significance] By analyzing the performance characteristics and underlying reasons for papers with continuous citation growth, this study reveals the relevant laws governing the sustained influence of academic papers. [Method/Process] Using the American Physical Society (APS) dataset as the data source, the BASS model was employed to identify papers with continuous citation growth. According to the 1:1 principle, papers without continu-

ous citation growth were selected as the control group, and the two groups were compared in terms of literature characteristics and citation diffusion networks. [Result/Conclusion] The results indicate that papers with continuous citation growth possess distinctive literature features and diffusion characteristics: they tend to have longer titles, are more commonly authored by individuals or pairs, and show lower dependence on previous research. Such papers exhibit more modular structures within their citation cascade networks and display a "broadcast-style" diffusion pattern over shorter intergenerational distances.

Keywords: continuous growth; literature characteristics; citation diffusion; network indicators; scientific influence

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1. Introduction

Since E. Garfield established the Science Citation Index [?], citation counts have been widely applied in scientific evaluation, serving as important indicators for measuring the significance, practicality, attention, and academic influence of research outputs. As research has deepened, scholars have proposed additional scientific evaluation metrics, though most remain based on citation relationships. Furthermore, citations can be used to analyze the dynamics of scientific development and are considered carriers of complex knowledge networks and scientific evolution, making citation analysis of knowledge transmission and evolution a current research hotspot.

When using citations to analyze the academic influence of scientific literature, scholars often focus on the temporal distribution of citation frequencies [?]. The time series of citation counts constitutes a citation curve, also known as a citation trajectory. Researchers have classified scientific papers' citation trajectories into different categories [?]. A paper's citation curve pattern is influenced not only by its own characteristics but also by citing behaviors, with these differences manifesting in both citation curves and citation diffusion networks and cascade structures.

Most literature experiences a lifecycle from publication and prosperity to aging and obsolescence. With the acceleration of scientific development, some scholars suggest that due to improvements in digital access and search services, the likelihood of older literature being discovered and utilized increases [?], thereby extending the literature lifecycle. Observing classic citation curve types reveals that during the period from publication until aging begins, the curve is nearly monotonically increasing. The longer this monotonic growth span, the higher the attention and recognition the literature receives, and the longer its lifecycle. If a paper's citation curve shows a continuous growth trend after publication, it belongs to the category of continuous citation growth papers. V. Cano et al. [?]

found that highly cited papers exhibit two lifecycle types—early rise and stable growth—with the latter maintaining stable citation growth after publication, demonstrating constant vitality. Wang Haiyan et al. [?] categorized highly cited papers into continuous growth distribution and peak-type distribution, where the continuous growth distribution curve possesses lasting academic influence because its proposed theories or methods are widely recognized.

Continuous citation accumulation relates to both content quality and external characteristics of papers. Although continuous citation growth papers have been mentioned in some studies, their underlying reasons and performance characteristics require further exploration. This study uses the BASS model to identify continuous citation growth papers as the experimental group and selects non-continuous citation growth papers as the control group. Drawing on common methods in citation growth influencing factors and citation diffusion network research, we analyze indicators of both groups to summarize their impact on continuous citation growth and explore influencing factors and knowledge diffusion characteristics by comparing citation network metrics.

The significance of this research lies in promoting scientific understanding of continuous citation growth papers, providing reference for discovering more citation patterns and improving the estimation of individual papers' scientific impact.

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2. Literature Review

2.1 Research on Academic Paper Citation Diffusion Citation diffusion research treats individual papers as basic units, analyzing knowledge generation, transmission, and innovation evolution through citation relationships. Domestic scholars have reviewed research from perspectives including citation networks [?], citation objects [?], and citation prediction [?], identifying mainstream topics such as diffusion measurement indicators, citation diffusion network and path identification, and diffusion structure and mechanism.

2.1.1 Citation Diffusion Measurement Indicators

Existing knowledge diffusion measurement indicators are constructed from four aspects: speed, breadth, intensity, and depth. For citation diffusion speed, R. Rousseau proposed the article-journal diffusion speed ADS (average diffusion speed) indicator based on citing journals [?], while Y. Liu et al. defined the discipline-discipline ADS indicator according to citing disciplines [?]. Knowledge transmission speed also manifests in citation accumulation rates [?]. For citation diffusion breadth, scholars have studied the disciplinary coverage of citing literature, proposing indicators such as JDF (journal diffusion factor) [?] and discipline citation rate [?]. T. F. Frandsen et al. suggested applying journal diffusion characteristic methods to individual paper knowledge diffusion research [?], and Y. Liu et al. [?] proposed the FDB (field diffusion breadth) indicator based on JDF to characterize knowledge diffusion breadth. Liang Guoqiang et al. [?] introduced the concept of entropy to measure disciplinary breadth of paper influence. Citation diffusion intensity research is closely related to breadth; for example, Y. Liu et al. [?] used the number of citing papers belonging to specific ESI fields as the diffusion intensity FDI (field diffusion intensity) in that ESI field. Citation diffusion depth is often reflected in citation cascade growth curves, where citation cascade research helps observe citation diffusion from microstructures [?].

2.1.2 Citation Diffusion Networks

Citation network research mainly includes network measurement indicator design and main path identification. For network measurement indicators, scholars have borrowed methods from graph theory, complex network analysis, and social network analysis to construct indicators such as network density, connectivity, centrality, cliques, characteristic path length, and clustering coefficient, explaining their meanings in the context of citation diffusion. For main path identification, Dong Ke and Zhang Bin suggested that related research mainly focuses on four aspects: disciplinary knowledge diffusion process, path identification, semantic analysis, and topological structure expansion [?]. Recent topics include constructing three-dimensional citation networks based on direct citation, co-citation, and bibliographic coupling relationships to mine knowledge theme flow characteristics [?], and analyzing diffusion characteristics of individual papers in knowledge networks [?].

2.1.3 Citation Diffusion Models

Scientific knowledge diffusion models often borrow mature models from other fields. Chen Baitong and Zhang Bin categorized existing models into three types: epidemic-like models, network growth models, and citation process-based models [?], reviewing the construction processes of classic models such as SEIRZ and SIR. In recent years, scholars have attempted to improve existing models or introduce new models to analyze citation diffusion mechanisms. For example, L. Zhang et al. [?] and C. Min et al. [?] further extended Bass model research in citation diffusion, while Z. He et al. improved the WSB model to explain intrinsic citation growth mechanisms for atypical citation curves [?]. S. Copiello introduced spatial autoregressive models to analyze peer effects and neighborhood effects in citation behavior [?].

2.2 Research on Paper Citation Growth Influencing Factors

Academic paper citation frequency and temporal distribution depend on numerous influencing factors. Scholars have conducted extensive research from perspectives including citer cognitive influence and bibliometrics.

2.2.1 Influencing Factor Analysis

Existing research explores four main angles. From the author perspective, studies have found correlations between citation frequency and author count [?], individual competitiveness [?], reputation [?], first author h-index [?], and team collaboration [?]. From the discipline perspective, some scholars focus on single disciplines, such as P. Ball [?] and L. Bornmann et al. [?] analyzing citation frequency factors in astrophysics and chemistry. Others compare different disciplines, such as Li Changling et al. [?] examining differences in evaluation indicators across disciplines. From the journal perspective, scholars have demonstrated that journal impact factor can promote citations [?], and L. Bornmann et al. found it useful for predicting citations, though its predictive power diminishes for older publications [?]. From the literature itself perspective, combining qualitative and quantitative methods, M. E. Falagas et al. [?] and P. Ball [?] found positive correlations between article length and citations, T. Liskiewicz et al. [?] suggested positive effects of title length and reference count on citation rates, while Jiang Lei et al. [?] proposed that reference quality does not significantly affect citations.

Citation trends are also influenced by these factors, though their intensity varies across contexts. S. Wuchty et al. found that over time, the advantage of team collaboration in gaining attention increases [?], and J. Wang et al. confirmed that reference disciplinary diversity positively impacts long-term citations while negatively affecting short-term citations [?].

2.2.2 Research Method Selection

Researchers mostly use regression analysis, with citation frequency as the dependent variable and influencing factors as independent variables. For example, L. Bornmann used multilevel regression models to find weak relationships between normalized citation impact (NCSs) and author count, reference count, page count, and journal impact factor [?]. Other methods include S. Jiang et al.'s multidimensional network framework using social capital theory to explore how researchers' collaborative experience, credibility, and career factors positively influence knowledge diffusion [?].

2.3 Review Overall, both research fields are mature. Scholars continuously deepen research on individual paper citation diffusion characteristics and growth mechanisms, attempting to construct new indicators and introduce more models to better explain citation diffusion phenomena, while examining influencing factors from multiple perspectives, though conclusions may differ. However, research on the formation reasons of specific citation curve types and detailed citation diffusion characteristics is limited, with few studies exploring influencing factors and knowledge diffusion features of continuous citation growth papers. Therefore, this study introduces literature and network characteristic indicators, using descriptive statistics and paired-sample nonparametric tests to discuss general patterns and features of such papers. As physics best represents basic research fields, we use it as the empirical field to identify continuous citation growth papers and compare their content/form characteristics and network similarities/differences with the control group to reveal general features and influencing factors.

3. Data and Methods

3.1 Data Research data comes from the American Physical Society (APS) dataset, including literature from 1893-2013. To identify continuous citation growth papers, this study applied the Bass model to the APS dataset. The model, developed by F. M. Bass [?], quantifies innovation and imitation mechanisms in innovation diffusion theory and is a classic model for analyzing product or technology diffusion processes. The Bass mathematical modeling principle is as follows:

$$f(t) = \frac{[A(t)]^2}{M} \cdot \frac{1}{1-F(t)} \cdot \frac{dF(t)}{dt} = p + qF(t)$$

In this formula, $f(t)$ represents the adoption portion at time t, $F(t)$ is the cumulative adoption portion from initial to time t, $A(t)$ is the cumulative number of adopters at time t, and p, q, M are the innovation parameter, imitation parameter, and total market potential (final adoption number), respectively.

Scholars have introduced this model to citation analysis. C. Min et al. [?] classified scientific papers into four groups based on Bass model parameters, where papers with smaller p and q values show continuous annual citation growth and have high academic influence and future potential scientific impact. This study uses the same method. First, the dataset was filtered to select "article" type literature with total citations \$ \$20 and citation windows >10 years, yielding 60,491 papers. Then, nonlinear least squares (NLS) were used for fitting, extracting 8,243 papers with non-negative parameters and $R^2 \geq 0.5$. Finally, 186 papers with both p and q values below their deciles were selected as the experimental group.

For better comparison, following existing research [?], a control group was established at a 1:1 ratio: for each paper in the experimental group, a paper published in the same journal in the same year with similar total citations was selected, resulting in 186 non-continuous citation growth papers. To illustrate differences between the groups, two example papers from each group were selected and their citation curves plotted in Figure 1 [Figure 1: see original paper].

3.2 Analysis Indicators Construction To compare influencing factors and citation diffusion characteristics between groups, literature and citation network features were obtained and calculated for each paper, with selected indicators shown in Table 1 . All indicators compare differences between experimental and control groups, focusing on research priorities without exploring internal logical relationships.

(1) Literature Characteristics. Five indicators were selected: paper title length, author count, paper length, reference count, and Price's Index [?]. These are commonly used indicators previously shown to correlate positively with citations [?].

(2) Network Characteristics. Citation diffusion research includes dynamic studies of citing processes. This study selects four generations of citing papers after publication to construct citation cascade networks, calculating three indicators commonly used to characterize network structure: network density, average clustering coefficient, and longest path length.

To measure literature novelty and creativity, the D-index (Disruption index) [**?**] was adopted, measuring scientific disruptiveness based on a paper's references and citing papers. The index is calculated as:

$$D = \frac{N_i - N_l}{N_i + N_l + N_k}$$

Where N_i is the number of citing papers that cite the target paper but not its references, N_l is the number of citing papers that cite both the target paper and at least one of its references, and N_k is the number of papers that don't cite the target paper but cite at least one of its references. A higher D-index indicates greater disruptiveness.

KS-tests analyzed all indicator data for normal distribution, with all P-values >0.05, rejecting the normality assumption. Therefore, the Wilcoxon signed-rank test was used to compare group differences. This nonparametric method improves upon sign tests, suitable for non-normal and unknown distributions, testing whether data come from the same population. To further examine significant differences, visualization was conducted for specific indicators.

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4. Results

4.1 Literature Characteristics Indicators Tables 2 and 3 show test results and descriptive statistics for literature characteristics. Data indicate no significant difference in paper length ($p = 0.1445 > 0.05$), but significant differences exist in title length, author count, reference count, and Price's Index. Figure 2 [Figure 2: see original paper] illustrates the comparison.

Table 2. Wilcoxon Signed-Rank Test Results for Literature Characteristics

Indicator	p-value
Title Length	0.0305*
Author Count	0.0001***
Reference Count	0.0286*
Price's Index	0.0076**
Paper Length	0.1445

Note: indicates $Sig. < 0.05$, ** indicates $Sig. < 0.01$, *** indicates $Sig. < 0.001$*

Table 3. Descriptive Statistics for Literature Characteristics

Indicator	Experimental Mean	Experimental SD	Control Mean	Control SD
Title Length	8.833	3.766	8.161	2.887
Author Count	2.651	1.122	3.590	2.038
Reference Count	21.039	14.725	17.554	12.731
Price's Index	0.615	0.311	0.735	0.267
Paper Length	47.681	22.201	47.317	17.317

As Figure 2 shows, both groups' title lengths concentrate in [4,13] words, with the experimental group's mean slightly higher. When titles exceed 8 words, experimental group papers are more numerous, indicating more long-title papers in this group.

For author count, significant differences exist ($p = 0.0001 < 0.001$). The control group mean is 2.038, lower than the experimental group's 2.887, meaning non-continuous growth papers average about one more author. The experimental group's standard deviation is much smaller, showing more concentrated distribution.

For Price's Index, significant differences also exist ($p = 0.0076 < 0.01$). The experimental group shows relatively uniform distribution, while the control group concentrates in [0.6,1.0]. The control group's mean is higher, indicating continuous citation growth papers have longer citation half-lives and slower obsolescence.

For reference count, despite minimal mean differences affected by extreme values, significant differences exist. Both groups show fewer papers with more references, but the control group has more papers in higher reference count intervals, suggesting continuous growth papers depend less on previous research.

4.2 Network Characteristics Indicators Tables 4 and 5 show test results and descriptive statistics for diffusion network indicators. No significant difference exists in network density ($p = 0.1078 > 0.05$), but differences exist in average clustering coefficient, longest path length, and D-index. Figure 3 [Figure 3: see original paper] illustrates the comparison.

Table 4. Wilcoxon Signed-Rank Test Results for Network Characteristics

Indicator	p-value
Network Density	0.1078
Average Clustering Coefficient	0.0001***

Indicator	p-value
Longest Path Length	0.0323*
D-index	0.0000***

Table 5. Descriptive Statistics for Network Characteristics

Indicator	Experimental Mean	Experimental SD	Control Mean	Control SD
Network Density	0.004	0.005	0.003	0.004
Average Clustering Coefficient	0.170	0.061	0.149	0.058
Longest Path Length	20.532	8.397	18.930	7.067
D-index	0.197	0.341	0.107	0.274

For average clustering coefficient, highly significant differences exist. The control group mean (0.149) is lower than the experimental group. The control group concentrates in (0.1,0.2), while the experimental group is more dispersed, indicating continuous citation growth papers' networks are more likely to be interlocked.

For longest path length, significant differences exist. The experimental group mean (20.532) exceeds the control group (18.930), suggesting continuous citation growth papers have longer diffusion paths and more complex networks.

Following P. Azoulay's [?] description of L. Wu et al.'s [?] D-index, if citing papers also cite many of a paper's references, the paper consolidates its field; otherwise, it disrupts the field. The D-index was calculated, showing highly significant differences ($p = 0.0002 < 0.0001$). The experimental group has higher D-index values, with more papers in the 0.3-0.8 high-value range, while the control group concentrates in [-0.1,0.1].

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5. Discussion and Conclusion

This study combines bibliometric indicators with citation diffusion theory, using physics as the empirical field to compare continuous and non-continuous citation growth papers in literature and network characteristics. The findings are: (1) Continuous citation growth papers tend to have longer titles, are more commonly authored by individuals or pairs, depend less on previous research, and more often reference older, less-noticed literature—features that relatively attract more citations; (2) Such papers have stronger scientific disruptiveness, with more modular structures in their citation cascade networks, presenting a "broadcast-style" diffusion pattern over shorter intergenerational distances that creates broad and profound future impacts.

As more methods for evaluating scientific value emerge, sustained paper impact becomes increasingly critical. Continuous citation growth paper characteristics are indicated not only in bibliometric metrics but also in citation behavior patterns, distinguishing them from ordinary papers and revealing formation and diffusion mechanisms. This detailed study of such citation curves aims to provide insights for scholars to enhance their research's sustained influence, offer references for early content quality assessment and objective indicators of potential scientific value, and serve transformative research development.

This analysis represents preliminary exploration with limitations: (1) It lacks attention to citation content—future work could use thematic analysis to study how target literature's value manifests in citing papers, and regression analysis to investigate specific reasons and drivers for continuous citation growth; (2) Using physics as the empirical field, disciplinary differences and dataset selection may affect results—continuous citation growth paper characteristics across disciplines and datasets warrant further exploration. Additionally, questions about predicting individual paper sustained influence at early stages, identifying reasons for continuous stimulation of follow-up research, and measuring potential sustained impact require deeper future investigation.

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Author Contributions:
He Jiejun: Proposed research idea, designed framework, collected and analyzed data, wrote paper.
Min Chao: Proposed research idea, provided guidance, refined research design.

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