Differences in Received Citations over Time and Across Fields in China

Siluo Yang[1], Junping Qiu[1], Jinda Ding[2] and Houqiang Yu[1]
[1] *58605025@qq.com*
School of Information Management, Wuhan University, Wuhan 430072, China
[2] *djdhyn@126.com*
Department of library, information and archives, Shanghai University, Shanghai 200444, China

Abstract
We analyse and compare the difference in discipline level of the received citations over a period of time and across fields in China by implementing the diachronous methods of bibliometrics. The citations of 896,645 papers from the Chinese Citation Database (1994 to 2013) that comprised four disciplines, namely, Philosophy, Library and Information Science (LIS), Physics, and Mechanical Engineering, are collected. Results indicate the following conclusions. First, the received citations strongly differ across various fields and over time. Second, the average of the received citations after a given year has an identical change. The number initially increases rapidly, and then declines slightly in the recent years. Uncitedness rate decreases in the early stage of the study period, whereas the rate stabilises or increases slightly in the recent years. Third, the average of the received citations peak after seven and nine years in mechanical engineering and philosophy, respectively, whereas both physics and LIS peak after three years. The span from the year of publication to the cited peak is relatively stable in LIS for 20 years. However, the span decreases in the early stage of the study period, and then stabilizes in the recent years for the other three disciplines. Recently, all four disciplines indicate relatively consistent citation trends. These results highlight the recent evolution of Chinese research systems towards relatively steady states.

Conference Topics
Citation and Co-citation Analysis; Country-level Studies

Introduction
Citing is a fundamental academic behavior among scholars. Citing shows the use of previous research, presents the processes of scientific inheritance and communication, and manifests respect for other scientific researchers (Yang et al., 2010). In the 20th century, citing other works became common in writing scholarly or scientific papers (Kaplan, 1965). Analysis of citing behavior is an important field and method in information science. At present, citation analysis is widely used to evaluate scientific works, initiate scholarly communication, analyse academic behavior, and process information retrieval (Hirsch, 2005; Hammarfelt, 2011; Ketzler & Zimmermann, 2013; Ding et al., 2014).

Information scientists have extensively investigated the distributions and changes of citing behavior (Finardi, 2014). According to the general theory of human behavior, we design the framework of citation behavior analysis. Figure 1 shows a four-dimensional model of citing behavior analysis. This model integrates analytical dimensions in terms of level (who), method (how), perspective (when), and content/topic (what and why). The combination of different dimensions can display the citing behavior in multiple functions and aspects. According to the analysis perspective, citing behaviors mainly include synchronic and diachronic distributions that fundamentally designate and refer to completely different characteristics of scientific literature (Nakamoto, 1988). Synchronic analysis is generally more common than other analytical approaches to citing behaviors (Heistermann et al., 2014). Line and Sandison (1974) proposed the diasynchronous analysis, a kind of synchronous analysis, which studies the synchronous distribution of cited documents at different time periods. Larivière et al. (2008) studied the evolution of yearly synchronous scores computed from 1900 to 2004. Their study showed the increase in average and median ages of cited literature, whereas the price index decreases over time. However, Egghe (2010) argued that

"Larivière' results do not have a special informetric reason but that they are just a mathematical consequence of a widely accepted simple literature growth model."

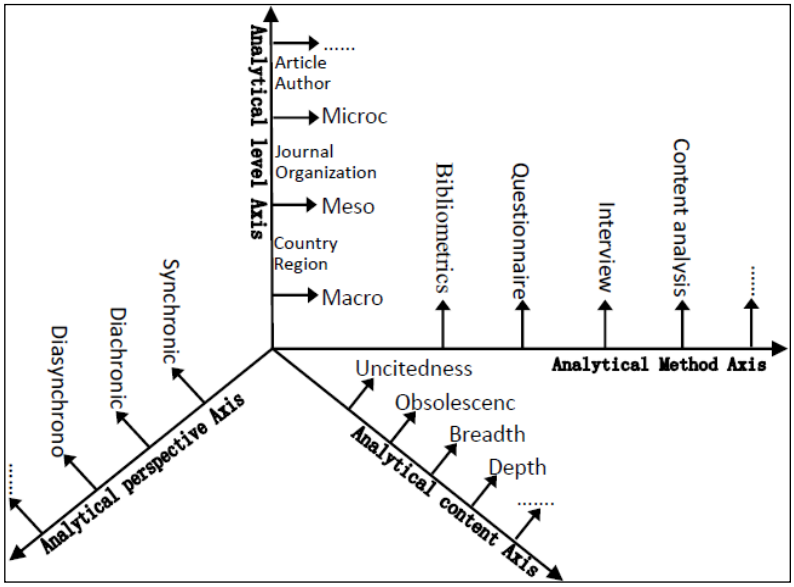

Figure 1. Four-dimensional model of citing behavior analysis.

Diachronic analysis consists of analyzing the distribution of citations gained over time by a publication within a given year by subsequent literature. However, this analysis is generally ignored because of the unavailability of data and the difficulty in implementation. Nevertheless, diachronic analysis has certain advantages, including its appropriateness for citation distribution (Bouabid & Larivière, 2013). Some papers focused on citation distribution and its evolution based on diachronic analysis. First, Finardi (2014) plotted the mean received citations against the time gap (in years) between the publication of the cited article and received citations. Afterwards, he established that citations follow different trends in various fields or disciplines. Some scholars studied the time gap between the publication of a scientific work, as well as the first citation it received (Bornmann & Daniel, 2010). Egghe et al. (2011) proposed a first-citation-speed index, which is utilised for a set of papers, based on the number of publication times and the initial citation. Bouabid and Larivière (2013) recently used a diachronous model to study life expectancy changes and to identify variations in life expectancy between countries and scientific fields based on the citations received by papers.

Second, studies focused on one intriguing aspect of citation analysis, which is the distribution of uncitedness. Schwartz (1997) defined uncitedness as the inability of papers to be cited in citation indexes within five years after their publication. Stern (1990) claimed that although most papers are eventually cited, a number of papers in various scientific disciplines are never cited. Pendlebury (1991) established that the lowest rates of uncitedness occurred among physics and chemistry papers. Garfield (1998) opined that knowing the number of uncited papers and clearly defining these prior to interpretation are important. Egghe et al. (2011) discovered that Nobel laureates and Fields medalists cover a large fraction (10% or more) of uncited publications. A positive correlation was found between the h-index and the number of uncited articles as well.

Lastly, some researchers investigated changes in citing behavior in the context of the overall situation. Larivière et al. (2008) studied the evolution of the aging phenomenon, particularly on how the age of cited literature has changed in over 100 years of scientific activity. They discovered that the average and median ages of cited literature underwent several changes during the period. Evans (2008) showed that as more journal issues are offered online, fewer

journals and articles are cited, and a large part of these citations refer to a small number of journals and articles. Larivière et al. (2009) challenged the conclusion of Evans (2008) and argued that the dispersion of citations is, in fact, increasing. Yang et al. (2010) studied citing behavior by employing three measures of citation concentrations using the Chinese Citation Database (CCD). The concentration of citations was claimed to be declining, and cited papers are broad and diverse. In our view, the diachronic analysis of citation behaviour has two main aspects: the citation change of papers **published** in different years and the citation change of papers **cited** in different years. However, scholars have yet to analyse received citations over a long period of time and across various fields in China.

Since 1978, when the reforms and opening up policies were implemented, China has experienced unprecedented changes. Chinese science exhibited remarkable progress as well. With the popularity of the Internet and development of computer networks in recent years, social environment and scientific research underwent significant changes (Zhou et al., 2009; Yang, 2010). In China, What is the exact general distribution of citation? What are the advancements in citation behaviour in Internet era? Are there differences in citation behaviour across various scientific fields in China?

Our research aims to discover the citation distribution trends over time in different scientific fields in China. Specifically, we focus on the following: (1) the general differences of citation distributions among disciplines, (2) the citation or uncitedness characteristic of papers **published** in different years (For example, papers published in 2000, 2001, 2002... are cited respectively after 5 years, that is, 2004, 2005, 2006...), and (3) the citation characteristic of papers **cited** in different years (For example, a paper published in 2000 is cited in 2000, 2001, 2002...).

Methods and data

Data sample

China has the following citation databases: Chinese Science Citation Database, Chinese Social Sciences Citation Index, Chinese Humanities and Social Science Citation Database, Chinese Science and Technology Paper Citation Database, CQVIP Citation Database, and CCD. In this study, we used CCD as our data resource. CCD collects all references for the China National Knowledge Infrastructure (CNKI) and performs deep data excavation on the citation relationship between studies. Furthermore, CCD provides a citation statistical analysis function based on authors, institutions, publishers, and journals. CCD is one of the products of CNKI (http://www.cnki.net/), and the database covers 6,642 journals while its web version has more than 8200 journals. CCD only contains Chinese journals. Tsinghua University and Tsinghua Tongfang Holding Group first launched CNKI in June 1999. CNKI is the key project of the national informatization construction in China, which established the most comprehensive system of academic knowledge resources (CNKI, 2014). CNKI comprises more than 90% of the knowledge resources in China, which is the broadest in titles and type coverages, as well as the most in-depth in years of coverage in the country. The oldest paper dates back to 1979. This database is updated daily.

We analysed publications and citations from 1994 to 2013, which spans 20 years, to identify publishing and citing patterns at the discipline level. This period was chosen because it is recent and 20 years is sufficiently long in performing the comparisons. All papers from 1994 to 2013 were collected in July 2014. The papers covered four disciplines based on the classification system of CNKI: philosophy, library and information science (LIS), physics, and mechanical engineering. These disciplines, respectively, represent the humanities, social sciences, science, and engineering. The LIS is somewhat peculiar given its evolution towards forms of publication and citation that are closer to the hard sciences. However, we are highly

familiar with this subject because many related research also use LIS as an example. We considered citation types including journals, books, dissertations, meetings, and newspapers. To verify the consistency of the data, we downloaded the data again after a week. We consulted the database provider several times regarding data access issues (i.e., the exact time of database upgrade per day and the range and scope of the citation database). The database is only appropriate for a country, and only reflects the situation in China. Thus, results may differ when international databases are used for comparison.

Methodology

Three aspects of related indicators of received citations across fields and over time are presented. The three aspects involve six equations.

Generally, the papers published in year *i* were cited in year *j*. Both *i* and *j* are from 1994 to 2013, and *j*>=*i*. P_j represents the number of papers published in year *i*. C_j represents the number of citations in year *j*, which were obtained from the papers published in year *i*. We analyse the general situation of the papers cited and published every year and analysed them using the following equations.

1) The average number of citations obtained by each paper from the published year to year *m* (*m* equals to 2013 in this study), and the average number of citations obtained by each paper in each year.

F1: $\frac{\sum_{j=i}^{m} C_j}{P_i}$ expresses the average number of citations obtained by each paper from the published year to year *m*.

F2: $\frac{F1}{n}$ expresses the average number of citations obtained by each paper in each year, where *n* represents the distance between published years *i* and *m*, that is, *n* = *m*-*i*+*1*.

2) Percentage of uncited papers within a given time period.

F3: $(1 - \frac{P^c}{P_i}) \times 100$, P^c is the number of papers cited at least once within a given time period after publication. The time span of one, two, or all years are set. In the case of three years, all papers published in 2003 are referred to as P_{2003}. We attempted to determine how many of the papers are uncited after three years (between 2003 and 2005). The time period ends in 2005 for the three-year perspective (including the publication year).

3) Time evolution of the average received citations.

We obtain Equation 4 by the methodology described in Finardi (2014).

F4: $MEAN_k = \frac{C_j}{P_i}$ expresses the average number of citations in year *j*, which were obtained by the papers published in year *i*. That is, the received citations of each paper in year *j* after being published for *x* (*x*=*j*-*i*+*1*) years (including the published year). At a constant value of *x*, which can be changed or assigned between 0 and 19 in the empirical analysis, we can obtain a series of $MENN_k$. For example, if we set *x* equals to 3, then we have $MEAN_1 = \frac{C_{1996}}{P_{1994}}$, $MEAN_2 = \frac{C_{1997}}{P_{1995}} \ldots MEAN_{18} = \frac{C_{2013}}{P_{2011}}$, where *k* is from 1 to *N* and *N* is dependent on *x* that equals to 2013-1993-*x*+1(*x* is the time distance between the published and cited years *i* and *j*, respectively).

F5: $AMEAN_x = \frac{\sum_{k=1}^{N} MEAN_k}{N}$ expresses the average of means among different occurrences from papers published in several years. By this equation, any possible bias because of the use of citations received in a single year may be avoided. The final result is the plot of $AMEAN_x$ vs. x.

F6: $CAC_x = \frac{\sum_{j=i}^{i+x} C_j}{P_i} \Big/ x$ expresses the cumulating average number of citations that each paper has received during x years, beginning its publication in year i (including the published year). For example, if i equals 2000 and x equals 3, the number of citations received at 2000, 2001, and 2002 from the papers published in 2000 will be summed, and then the cumulating average values of received citations of each paper per year will be calculated.

Result and discussion

Overview

A total of 896,645 papers in philosophy, LIS, physics, and mechanical engineering that were published from 1994 to 2013 were collected. The upper left curve in Figure 2 shows that 41,793,391 papers were published across all fields in CCD for the past 20 years (1994 to 2013). The number of papers steadily increased each year, from 927,684 in 1994 to 3,478,490 in 2013. The curve shows that the growth pattern is an S-shape and has three stages (i.e., slow, rapid, and slow growth). The growth of scientific papers slowed down after 2008. The progress of LIS and philosophy papers remains consistent with those of the other fields. However, a downward trend in physics and a highly irregular trend in mechanical engineering in the recent years are observed. Instead of using typical journals, we selected sample papers in the selected disciplines by an artificial category classification of the database. Numerous papers in China are being published in international journals, especially those in the science and technology field, resulting in changes in the growth rate in Chinese journals.

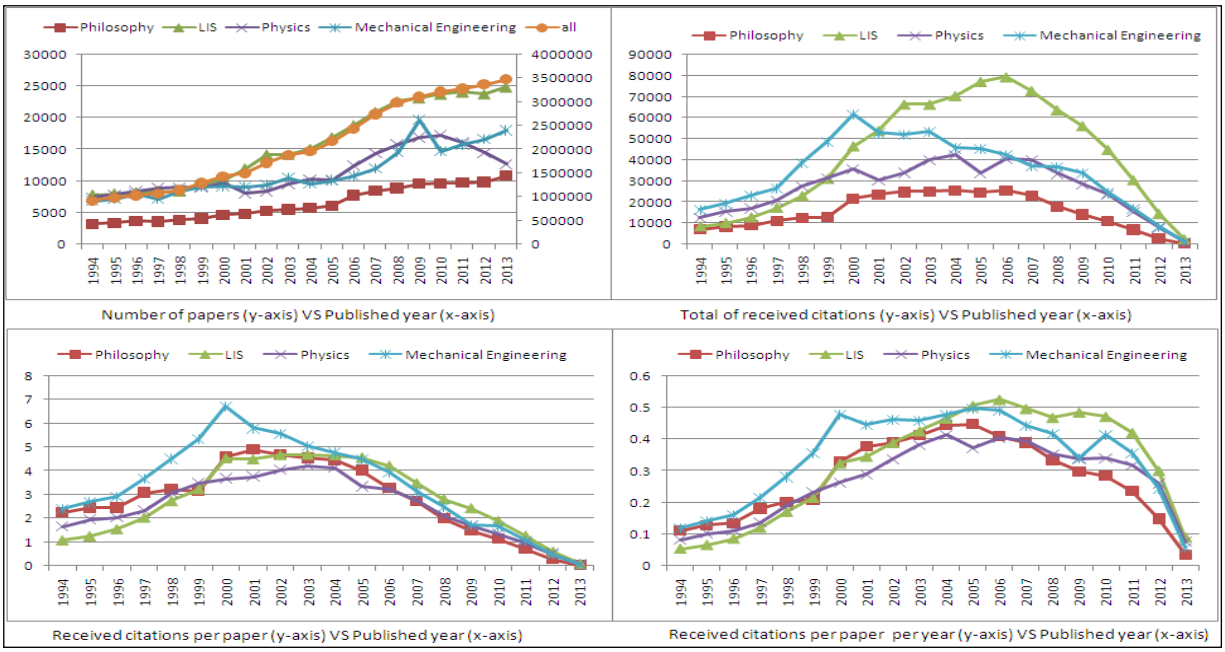

Figure 2. Overall situations of received citations across four disciplines.

Figure 2 shows the overall situations of received citations across four disciplines in CCD. The curves of the received citations exhibit an arch shape (i.e., the middle is high and the end is low). A paper published a long time ago generally has increased chances of receiving citations because of the cumulative phenomenon. However, Figure 2 exhibits the trend of received citations in all four subjects as from increasing in the early periods of the study period to decreasing in the recent years. This phenomenon is caused by two reasons. First, the number of published papers and references for each paper increases each year. The rapid updating of information and the increase in the received citations of each paper can lead to the increase in the number of citations (Price, 1965). Therefore, the cumulative effect of received citations is weakened. Second, people are generally interested in and use the latest research as reference. Researchers strive to make their papers novel. Thus, papers published in previous years have become irrelevant. Figure 2 also exhibits that the received citations of each paper each year (bottom right corner of the figure) eliminate the accumulation phenomenon and display the advantages of papers published in the recent years. The curves of the total received citations and the number of papers published in a specific year are generally consistent. LIS indicated the largest number of papers and received citations in the recent years, whereas philosophy recorded the lowest.

Citation and uncitedness characteristics of papers published in different years

Figures 3 and 4 show the average of the received citations after a paper is published in a given year. In the case of five years window, all papers published in 2000 were taken as the research sample; we determined the average number of times that these papers were cited in 2004. For clarity of presentation, Figure 3 displays only the received citations in four fields after 1, 2, 5, and 10 years. The curves exhibit an identical change (i.e., an initial rapid increase and then a slight decline in the recent years) and indicate that the average of the received citations (published in the recent years) failed to increase. The rapid growth of the average of the received citations in the early stages of the study period changes to a relatively stable development phase because of the slow growth in the number of published papers, the development of the Internet, and the widespread use of open-access and e-print materials. However, whether a special informetric reason or merely a mathematical consequence of a simple literature growth model exists, this phenomenon requires further validation and

investigation (Egghe, 2010). The average of the received citations exhibits significant differences among the four disciplines in various time spans. The maximum value was attained by LIS after one, two, and three years compared with the other three disciplines in each publication year. However, this value slowly decreased, and LIS attained the minimum value each year after 10 years. Physics and mechanical engineering show the exact opposite of LIS. That is, after 10 years, the maximum value of the average of the received citations was achieved.

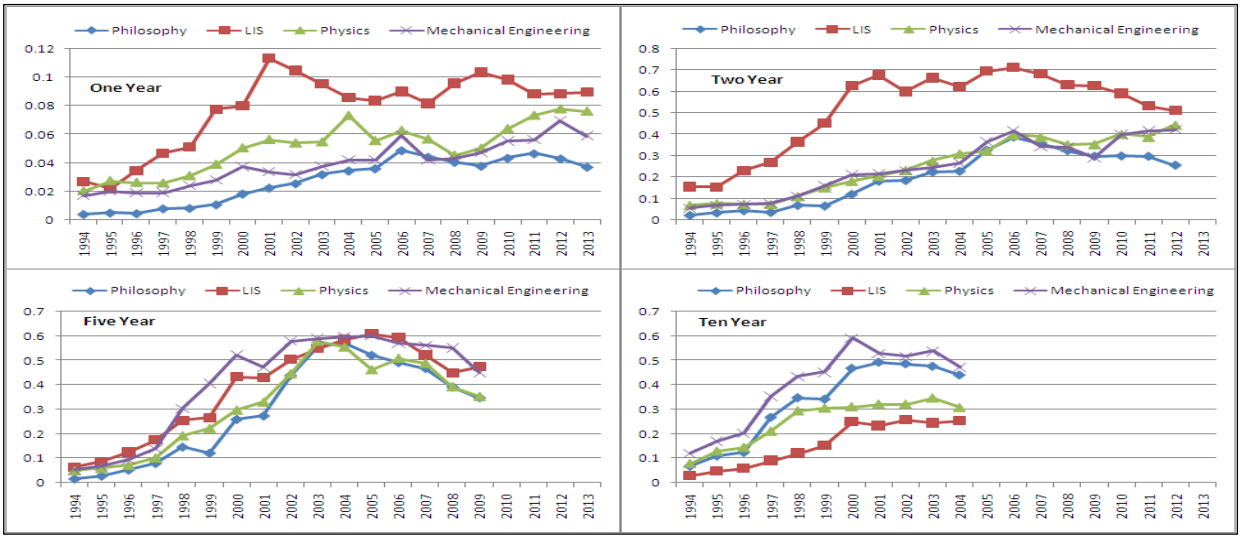

Figure 3. Received citations of each paper each year (y-axis) vs. published year (x-axis) (Part I).

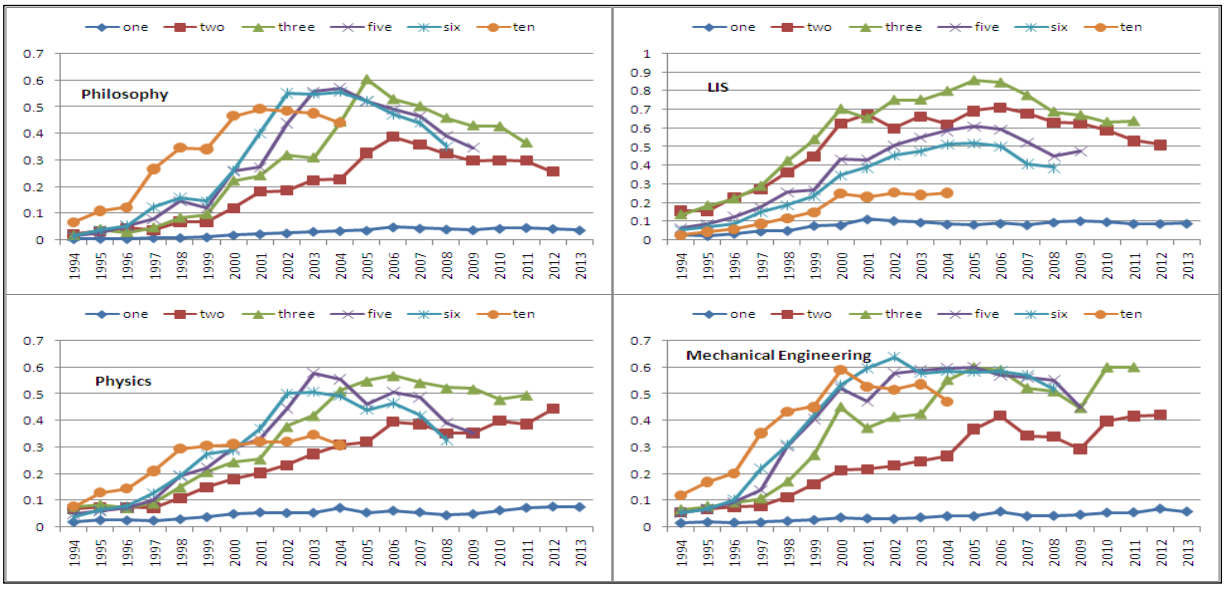

Figure 4. Received citations of each paper each year (y-axis) vs. published year (x-axis) (Part II).

Figure 4 illustrates the received citations by discipline and clarifies the situations of various time spans in each field. Philosophy, physics, and mechanical engineering papers published in the early stages of the study period received more citations in six and ten-year windows than in the recent years. Generally, recently published papers have more citations of papers published from the last three years, which implies that the life expectancy of scientific

literature is generally becoming shorter. Papers on LIS (published almost all year) received more citations in two and three-year windows.

The uncitedness results are presented in four citation windows representing one, two, five, and all years after the publication year. Figures 5 and 6 show that the uncitedness rate generally decreases in the early stages of the study period, and then stabilises or increases slightly in the recent years. This phenomenon is due to the following reason. First is the emergence of databases and networks that provided researchers with additional opportunities to find articles for citation and that allowed equal access to all documents. However, the development of databases has entered a period of relative stability in recent years and the uncitedness rate changes slowly as well. Second, the steady increase in the number of published articles and references for each paper decreases the uncitedness rates in the early stages of the study period. However, the rates of both published articles and references relatively stabilised in the recent years. Third, CCD, which is used and promoted in a wide range of areas, was established in 1999. As CCD became increasingly stable, its data updates became timely in recent years. After the reform, the opening up, and the development of science and technology, research conditions and environments significantly improved. The state of scientific research has become steady in recent years in China.

A number of studies showed that the uncitedness rate is lowest in the sciences, high in the social sciences, and highest in arts and humanities (Hamilton, 1991). However, Figures 5 and 6 display contrasting results. The uncitedness rates in LIS are significantly lower than the other three disciplines in the one-, two-, and five-year citation windows in almost all publication years. A possible reason for this phenomenon is the privileges and required expertise in accessing and using documents (especially online information retrieval) in LIS. Papers published in the recent year exhibit high uncitedness rates for Philosophy in the one-, two-, and five-year citation windows. However, the low uncitedness rates in the all-year citation window showed more documents being cited in this discipline.

Figure 6 shows the uncitedness situation by discipline. The curves exhibit the same trend for all four disciplines. The uncitedness rates in the one-year window are relatively stable, while in the two-year window, the uncitedness rates decrease rapidly and decline sharply in the five-year window. However, the all-year window is special because different results were obtained for papers in different publication years. For example, papers published in 1994, 2000, and 2008 are in the all-year citation window, particularly 20, 14, and 6, respectively. Consequently, the two curves of the five- and all-year windows move gradually closer.

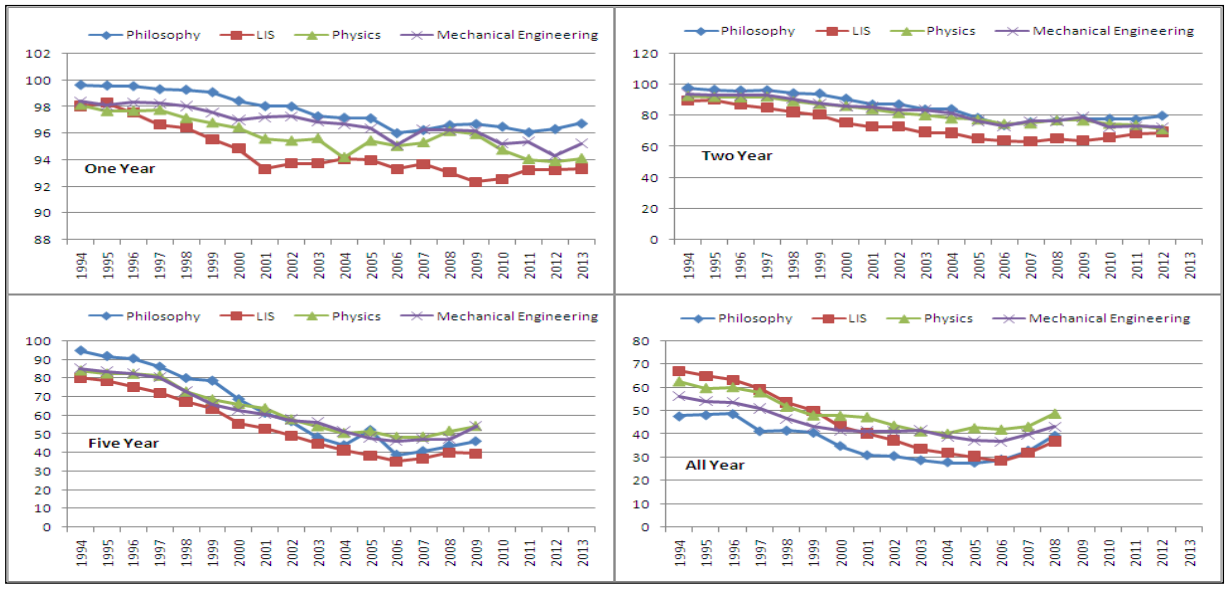

Figure 5. Number of uncited articles (y-axis) vs. published year (x-axis) (Part I).

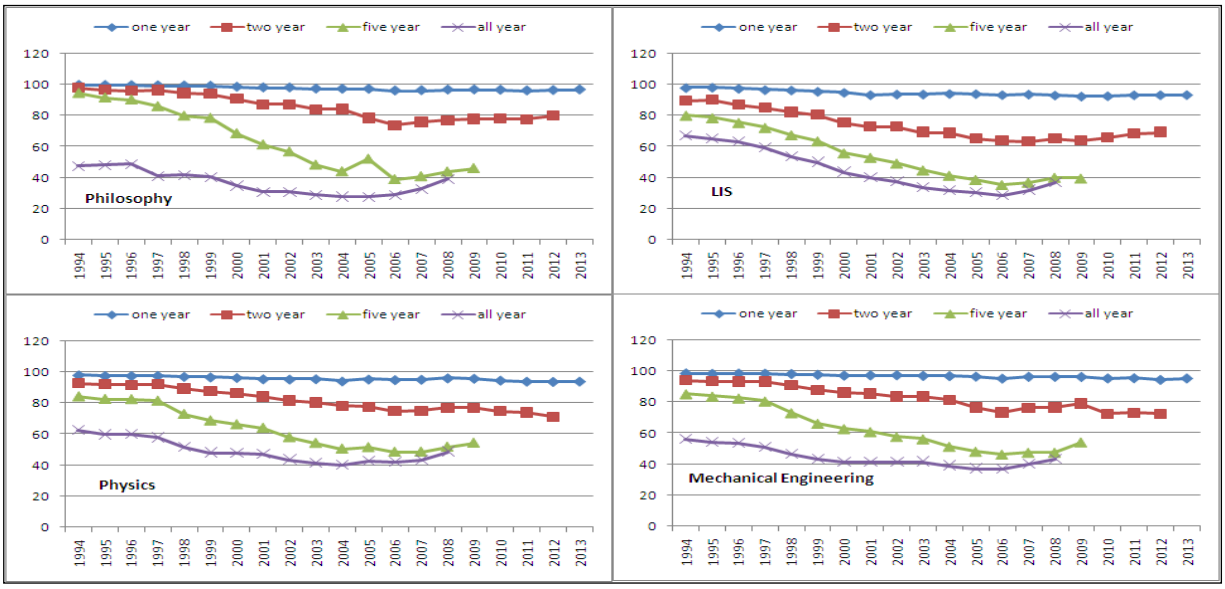

Figure 6. Number of uncited articles (y-axis) vs. published year (x-axis) (Part II).

Citation characteristics of papers cited in different years

Figure 7 shows the mean of the received citations of each paper after a given time period using Equations 5 and 6. The average value avoids possible biases that are caused by using the received citations in a single year. The curve shows the values from 1 to 20 years after publication.

Figure 7 presents the average of the received citations over time. The typical citation curve starts with a rapid increase during the initial years followed by a peak, and then a slow but steady decrease (Larivière et al., 2008). LIS and physics had a similar trend in terms of the average of the received citations. These disciplines peaked at three years after publication, as observed by Finardi (2014) and Bouabid & Larivière (2013). However, physics steadily decreases and LIS rapidly decreases, which created a steep curve. The times of cited peak values are distinct among different disciplines. The trend of mechanical engineering presents a peculiar behaviour because a peak is not exhibited. Instead, the received citations increase in the first three to five years and then stabilise at high values. Citations of mechanical engineering papers continue for a long time after their publication. Figure 7 also suggests that philosophy has a different citation path, with the continuous growth from one to eight years, peak at nine years, and a subsequent slight decrease. This trend is because philosophy information can be accessed and used for a long time, with slow obsolescence.

Figure 7 shows that notable differences exist between the trends of the mean of the received citations in different fields. Consequently, we can conclude that clear differences exist among other specific fields of natural and social sciences. However, further evidence must be obtained by using longer time periods and increasing the number of disciplines compared with that in this study. The maximum values of the average of the received citations peaked after seven years in mechanical engineering and nine years in philosophy. The journal impact factor (IF) only considers citations received in the first two or five years after publication (i.e., 2-years IF or 5-years IF). Thus, high citation values are not captured in the IF computation. The following reasons can explain the particular trends in mechanical engineering and philosophy. Papers published in both disciplines increased from 1994 to 2013, resulting in a parallel growth in the number of citations. Moreover, referring to old literature is preferred in both disciplines, resulting in stable citation curves.

The curves at the right of Figure 7 represent the cumulating value. The curves of the right and left categories in Figure 7 are relatively consistent. However, the curves on the right are smoother than the curves on the left, and the corresponding peaks lag for several years because of the average cumulative effect. For example, in the case of x=3 (x-axis) in Equation 6, we calculated the number of received citations published after one, two, and three years, and then calculated the average values of the received citations of each paper each year.

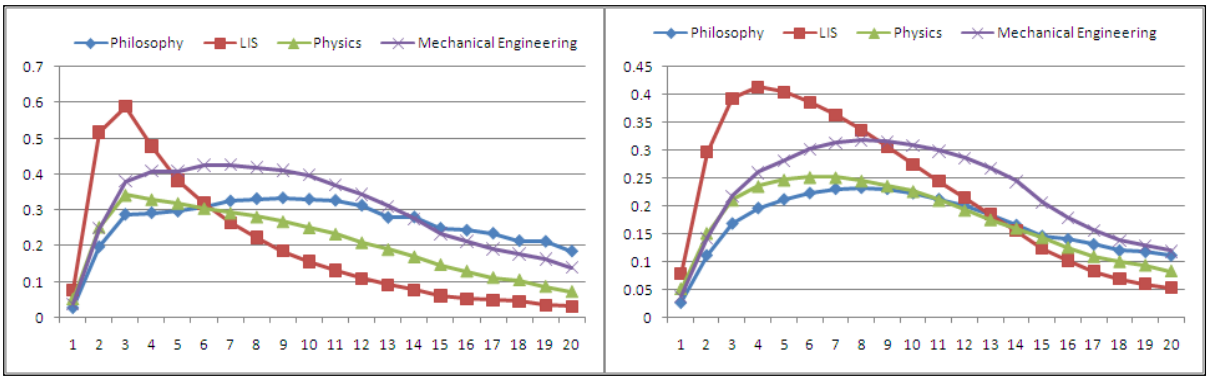

Figure 7. $AMEAN_x$ **(y-axis) vs.** x **(x-axis).**

Figure 8 shows the received citations of each paper each year within the identified time period. We selected the publication years of 1994, 1998, 2002, and 2008 as representatives. The data for the other years of publication showed the same trends. However, these were not included in this paper. The trend in LIS is completely different from those of the other three disciplines. LIS presents a peak at two or three years, which slightly decreases in all cited years. The curves of the other three disciplines are relatively consistent. The received citations of papers published in 1994, 1998, and 2002 increase tremendously and peak in 2006 before slightly decreasing. However, a big difference is observed in the received citations for papers published in different years (i.e., 1994, 1998, and 2002). We can conclude that the early publication years tend to have late citation peaks. For example, the received citations of philosophy papers published in 1994 exhibited their peak 14 years after publication (2007), whereas papers published in 2002 exhibited their peak six years after publication (2007). In general, all four disciplines possess a relatively consistent citation trend in recent years.

Figure 9 shows the situation of the received citations by discipline. Philosophy papers published in the early part of the study period still received many citations. These old papers are not excluded from the science system. Thus, they remain to have a relevant contribution. The citation curves in LIS are consistent in the different cited years. However, the curves of the other three disciplines exhibit a similar trend; papers in these three disciplines became more quickly obsolete in general in recently. Furthermore, many curves peak between 2006 and 2008.

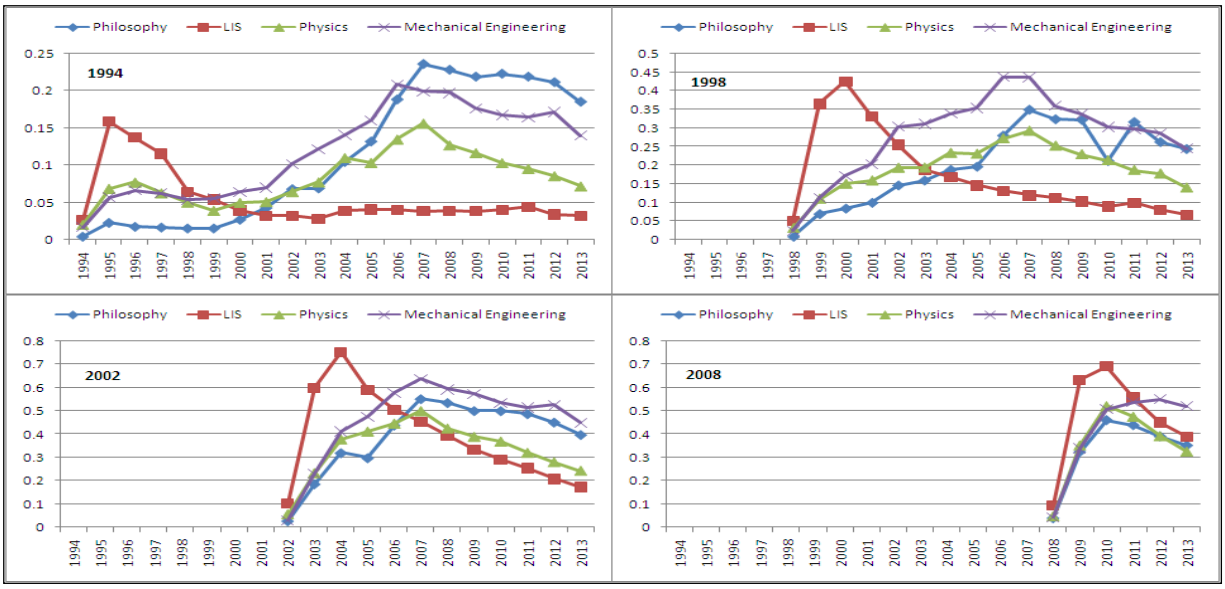

Figure 8. Received citations of each paper each year (y-axis) vs. cited year (x-axis) (Part I).

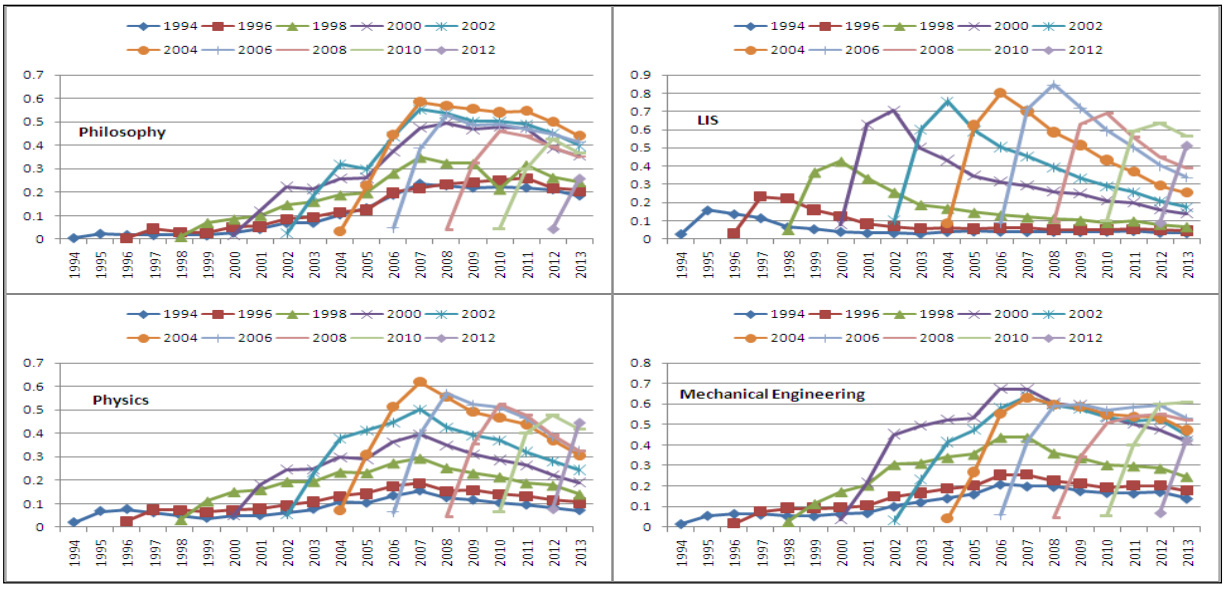

Figure 9. Received citations of each paper each year (y-axis) vs. cited year (x-axis) (Part II).

Conclusion and further research

A total of 896,645 papers on philosophy, LIS, physics, and mechanical engineering, which were published from 1994 to 2013, were collected. This study analysed the differences of these papers in terms of the received citations across fields and over time in China. The following conclusions were derived from the results. First, the growth of published papers is generally S-shaped and undergoes three stages (i.e., slow growth and rapid growth). The curves of the received citations of each paper exhibit an arch shape (i.e., the middle is high and the end is low). The cumulative phenomenon of received citations is not obvious. Second, the average of the received citations in a given year window changes identically, initially increases rapidly, and then slightly decreases in the recent years. The average of the received citations exhibits significant differences among the four disciplines in various time spans. In one-, two-, and three-year windows, a maximum value is observed in LIS in each published

year. The value slowly decreases until the LIS obtains a minimum value within the 10-year windows. However, physics and mechanical engineering exhibit an exactly opposite change. Third, the uncitedness rate generally decreases in the early stages of the study period, but stabilises or increases slightly in recent years. The uncitedness rates in the one-year window are relatively stable, but decreases rapidly in the two-year window and drops sharply in the five-year window. Fourth, notable differences exist among the trends of the mean of the received citations of the different fields. The maximum values of the average of the received citations peak after seven years for mechanical engineering, nine years for philosophy, and three years for both physics and LIS. These results are similar to those obtained by Finardi (*2014*) and Bouabid & Larivière (*2013*). Lastly, citation characteristics of papers cited in different years. LIS citations are completely different from those of the other three disciplines. LIS citations peak at two or three years and then slightly decrease in all cited years. The curves of the other three disciplines are similar. Papers published in the early stages of the study period have a later cited peak. In the recent years, all four disciplines possess a relatively constant citation trend. Generally, Chinese research systems evolve into a relatively steady state from a rapid growth and then change in the early period.

This study has analysed comprehensively the received citations across fields and over time in a systematic manner. As a result, consistent conclusions are drawn. For future research, we intend to perform the following. First is we will measure the received citations at the discipline level by implementing diachronous methods. We will consider synchronic methods and combine the two methods. Aside from the discipline level, other levels (e.g., journals, authors, countries, papers, agencies) will also be analysed. We intend to study citations based on literature units and analyse large-scale samples using probability statistics. Second is we will increase the number of disciplines. We will choose additional representative samples from other disciplines for a comprehensive statistical analysis. Furthermore, we will select other document databases such as international document databases, to verify the pattern and characteristic changes in the received citations. Third is we will increase the level of examination and improve the measured indicators of distribution and evolution of the received citations. The measurement methods of the received citations can be enhanced, and an in-depth analysis of the specific distribution of highly cited papers will be conducted. Lastly, a detailed and in-depth study will be implemented to check the factors that affect citation evolution and examine the cause and effect of these changes (e.g., the effect of the growth in number of papers on received citations). Furthermore, we will determine how to handle the trend and changes in the distribution of the received citations.

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