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The influence of publication delays on three ISI indicators

GUANG YU, RUI GUO, YI-JUN LI

School of Management, Harbin Institute of Technology, Harbin (P. R. China)

Based on the transform function model of the observed citing process, the analytical expression of the age distribution of citations is deduced, and it is theoretically proved that the peak value of the citation distribution curve would fall and shift backward along with increasing the average publication delay and the peak age has a direct proportion relation with the pure delay and would be prolonged along with increasing the delay or decreasing the aging rate. The influence of the average publication delay on three ISI indicators impact factor, immediacy index and cited half-life are studied; in one subject discipline, the bigger the delay, the lower the three indicators of journals. Using the sensitivity theory, sensitivity formulae of the three indicators to publication delay parameters are deduced and it is found that responses of these indicators to changes of publication delays are different according to different time constant of the aging process; The faster the aging rate of a discipline literature is, the worse the influence of publication delays on the indicators of journals in the discipline.

Introduction

The ISI indicators impact factor, immediacy index and cited half-life are three standardized measures which are related with citations. AMIN & MABE (2000) described the build-up of citations over time after publication using the generalized citation curve in Figure 1. Citations to articles published in a given year rise sharply to a peak between

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Address for correspondence:
GUANG YU
Library, Harbin Institute of Technology
No. 17, Silin Street, NanGang, Harbin, 150001, Heilongjiang, P. R. China
E-mail: yug@hit.edu.cn

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two and six years after publication, from this peak citations decline exponentially. The citation curve of any journal can be described by the relative size of the curve (in terms of area under the line), the extent to which the peak of the curve is close to the origin, and the rate of decline of the curve. The three indicators can be used to measure the way a journal receives citations to its articles over time (AMIN & MABE, 2000).

LUWEL & MOED (1998), GARFIELD (1999) and MARCHI & ROCCHI (2001) have taken notice of influence of publication delays on the citation distribution and the impact factor. Based on the research-citation cycle pictured by EGGHE & ROUSSEAU (2000), YU et al. (2005) proposed a concept of *the delay effect of literature citation* and illuminated that there exists theoretically an inverse relation between the field (or discipline) average publication delay and the journal impact factor using the simulation method. But inherent relations between the indicator and some parameters of the publishing process cannot be obtained using this method. In this paper, according to the transfer function model of the observed citing process (YU et al., 2005), we will deduce the analytical expression of the cumulative citation distribution and quantitatively study the influence of publication delay on the three indicators and find relations between three indicators and parameters of the publishing process or the aging process. The "notion" publication delay is defined here as the average publication delay of articles published in one scientific discipline (or field) and is the same as that in the paper (YU et al., 2005), the citation distribution is regarded as the age distribution of references in the discipline (or field) or any journal in the discipline (or field), three indicators are regarded as the indicators of any journal in the discipline (or field).

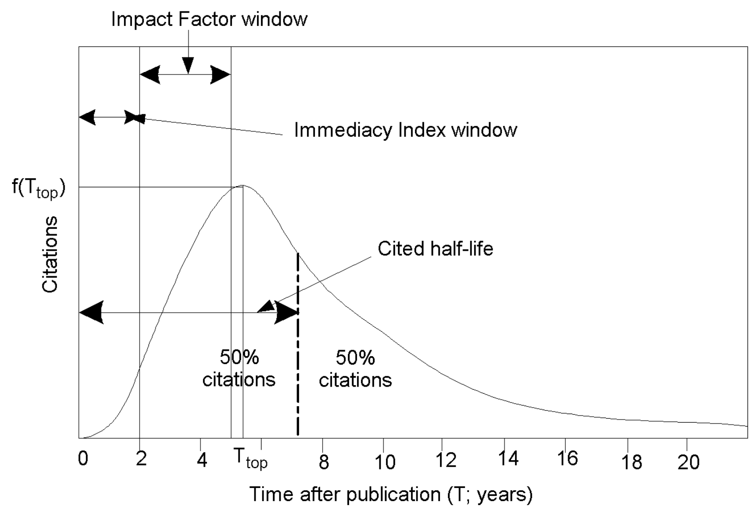

Figure 1. The generalized citation curve and three ISI indicators

Table 1. Main variables

Symbol	Name and concept
$C(T)$	the cumulative citation distribution function disturbed by the delay
$f(T)$	the disturbed citation distribution function
$f(T_{top})$	the peak value of the citation distribution curve
T_{top}	the age of peak of the citation distribution curve
$\overline{T}$	The average publication delay of the discipline, $\overline{T} = \tau + T_s$
T_s	the time constant of the publishing process
τ	the pure delay
T_1	the time constant of the aging process
IF	the impact factor of a journal
Im	the immediacy index of a journal
$T_{0.5}$	the cited half-life of a journal
$\frac{\partial IF}{\partial \tau}$	the sensitivity of IF to the pure delay τ
$\frac{\partial IF}{\partial T_s}$	the sensitivity of IF to the time constant T_s
$\frac{\partial Im}{\partial \tau}$	the sensitivity function of Im to the pure delay τ
$\frac{\partial Im}{\partial T_s}$	the sensitivity function of Im to the time constant T_s
$\frac{\partial T_{0.5}}{\partial T_s}$	the sensitivity function of the cited half-life to the time constant T_s

The disturbed citation distribution function

For studying the question in theory, we suppose the citation distribution of one journal is same as that of its discipline (or field) and the single-factor method is used, namely the publication delay is regarded as a main factor influencing the three indicators and other factors are neglected (YU et al., 2005).

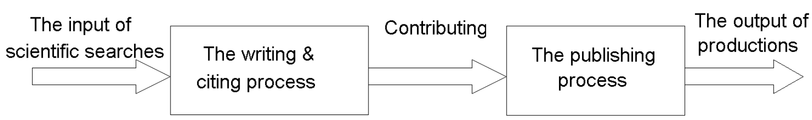

Figure 2. The citing and publishing processes of scientific literature (YU et al., 2005)

The analytical expression of the disturbed citation distribution

The observed citing process includes the citing and publishing processes of scientific literature in Figure 2. Based on the convolution expression of the disturbed citation distribution proposed by EGGHE & ROUSSEAU (2000), YU et al. (2005) established the transform function model of the disturbed citing process as follows:

$$W(s) = \frac{e^{-\tau s}}{(T_1 s + 1)(T_s s + 1)} \tag{1}$$

In Eq.1, T_1 is called as time constant and nearly related to the aging coefficient α, $T_1 = 1/\alpha$, the bigger T_1 is, the slower the rate of subject development and the knowledge updating rate are, whereas the faster the rate of subject development and the knowledge updating rate are. T_s is another time constant related with the average publication delay, τ is the pure publication delay, the average publication delay: $\overline{T} = \tau + T_s$. T_s is the rate of the deposited contribution quantity N to the published contribution flux Y (YU et al., 2004), the bigger T_s or τ is, the more contributions are deposited and the longer the publication delay is, and the worse the delay influence on the citation distribution of the discipline is.

In that paper (YU et al., 2005), we proposed that the input $X(T)$ of the actual citing process is citing action of authors and is described as: *total citing frequency/the total of citations=I*. It is a step function and dimensionless, its expression is:

$$X(T) = \begin{cases} 0, T = 0 \\ 1, T > 0 \end{cases} \tag{2}$$

According to inverse Laplace transform of Eq. 1 and the input function Eq. 2, we can deduce the analytical expression of the output response of Eq. 2:

$$f(T) = \frac{e^{-\frac{T-\tau}{T_1}}}{T_1 - T_s} - \frac{e^{-\frac{T-\tau}{T_s}}}{T_1 - T_s} \tag{3}$$

Eq. 3 is the age distribution function of citations and describes the relation between the citation distribution function and parameters T_1, T_s and τ, and should be an effective tool for quantificationally studying the influence of the publication delay on the citation distribution.

Because the cumulative citation distribution function $C(T)$ can be obtained by the integral of the citation distribution function $f(T)$, so $C(T)$ can be obtained:

$$C(T) = 1 - \frac{T_1 \cdot e^{-\frac{T-\tau}{T_1}}}{T_1 - T_s} + \frac{T_s \cdot e^{-\frac{T-\tau}{T_s}}}{T_1 - T_s} \tag{4}$$

The peak value and the peak age of the citation distribution curve

From those simulation results in the paper (YU et al., 2005), the change of the pure delay τ would cause the remove of the citation distribution curve, namely when the pure delay τ were increased the citation distribution curve would be shift parallel backwards; when the time constant $T_s = N/Y$ were increased the peak value of the citation distribution curve would fall and shift backwards. It will be proved using a theory analysis of the citation distribution function in this paper.

We suppose that T_{top} is the peak age in Figure 1. According as the condition of the peak value of the citation distribution curve is:

$\left.\frac{\partial f}{\partial T}\right|_{T=T_{top}} = 0$ and Eq. 3, we can educe

$$\frac{1}{T_1}\frac{e^{-\frac{T_{top}-\tau}{T_1}}}{T_1 - T_s} = \frac{1}{T_s}\frac{e^{-\frac{T_{top}-\tau}{T_s}}}{T_1 - T_s} \quad . \tag{5'}$$

Predigesting Eq. 5', we get $\frac{1}{T_1}e^{-\frac{T_{top}-\tau}{T_1}} = \frac{1}{T_s}e^{-\frac{T_{top}-\tau}{T_s}}$ and then obtain the peak age T_{top} as follows:

$$T_{top} = \tau + \frac{T_s T_1}{T_1 - T_s} \cdot ln\frac{T_1}{T_s} \tag{5}$$

Combining Eq. 3 with Eq. 5, we obtain the peak value $f(T_{top})$ of the citation distribution curve:

$$f(T_{top}) = \frac{1}{T_1 - T_s}\left(e^{-\frac{T_s}{T_1 - T_s}ln\frac{T_1}{T_s}} - e^{-\frac{T_1}{T_1 - T_s}ln\frac{T_1}{T_s}}\right) \tag{6}$$

According to Eq. 6, $f(T_{top})$ is not related with τ. We suppose that τ equals 0.3 year and can obtain the relation curve of $f(T_{top})$ with the parameter T_s according to different T_1 .

From Eq. 5, it is shown that the peak age T_{top} has a direct proportion relation with τ and is prolonged along with increasing T_s or T_1 . Figure 3 shows the graphs of $f(T_{top})$ vs T_s with different T_1 values (8, 10, 12, 14 years). So it is proved in theory that the increase of the average publication delay would result in the shift backwards and the fall of $f(T_{top})$; $f(T_{top})$ is not influenced by the pure delay and just fall along with increasing the time constant T_s or T_1 .

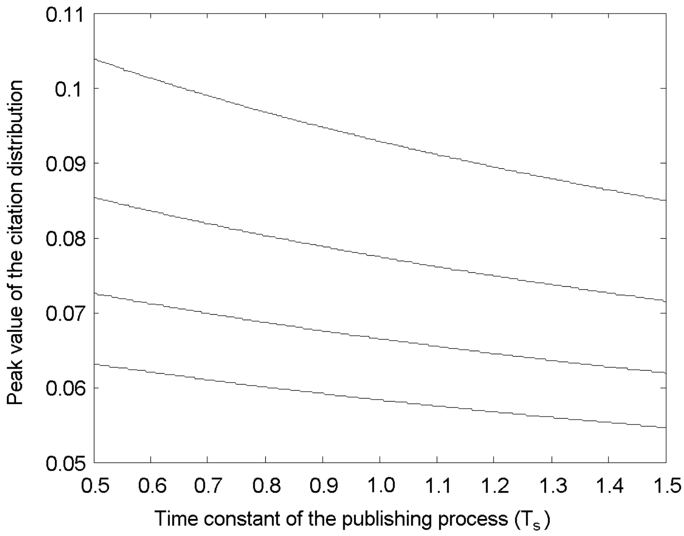

Figure 3. Graphs of $f(T_{top})$ vs T_s (T_1 =8, 10, 12, 14 years, respectively, from top to bottom)

The influence of publication delays on three ISI indicators

Impact factor

The *impact factor* (abbreviated as *IF*) is a measure of the relative size of the citation curve in years 2 and 3. It is calculated by dividing the number of current citations a journal receives to articles published in the two previous years by the number of articles published in those same years. According to the definition of *IF* and the *IF* window in Figure 1, we have $IF = K \cdot (C(3) - C(1))$ and can deduce the calculation formula of *IF* using Eq. 3:

$$IF = K \cdot \left(\frac{T_1 \cdot (e^{-\frac{1-\tau}{T_1}} - e^{-\frac{3-\tau}{T_1}})}{T_1 - T_s} - \frac{T_s \cdot (e^{-\frac{1-\tau}{T_s}} - e^{-\frac{3-\tau}{T_s}})}{T_1 - T_s} \right) \qquad (7')$$

In Eq. 7', *K* is a constant which has a relation with total citations and publications of a journal and is unchangeable according hypotheses, so we may suppose *K*=1, and Eq. 7' is rewritten as:

$$IF = \frac{T_1 \cdot (e^{-\frac{1-\tau}{T_1}} - e^{-\frac{3-\tau}{T_1}})}{T_1 - T_s} - \frac{T_s \cdot (e^{-\frac{1-\tau}{T_s}} - e^{-\frac{3-\tau}{T_s}})}{T_1 - T_s} \tag{7}$$

According to Eq. 7, when $\tau = 0.3$ year, we calculate graphs of the impact factor disturbed by different average publication delay with different T_1 values (8, 10, 12, 14 years) in Figure 4. It is shown that the bigger increment the average publication delay in a scientific field, the more fall the impact factors of journals in the field.

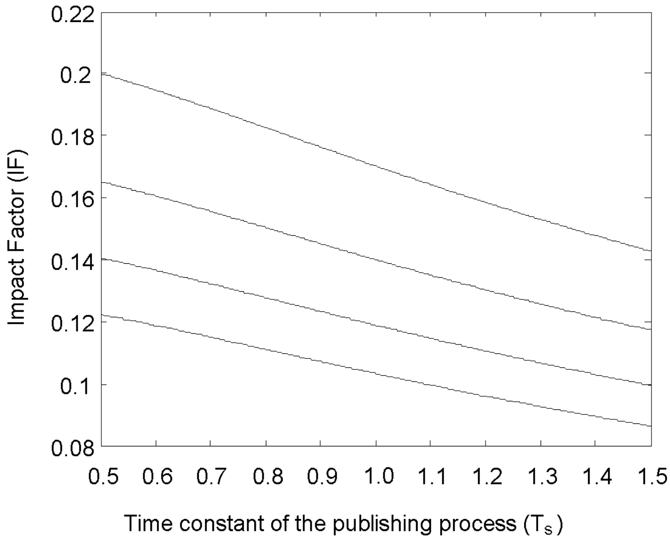

Figure 4. Graphs of *IF* vs T_s (T_1 =8, 10, 12, 14 years, respectively, from top to bottom)

Immediacy index

The immediacy index (abbreviated as *Im*) gives a measure of the skewness of the curve, that is, the extent to which the peak of the curve lies near to the origin of the graph. It is calculated by dividing the citations a journal receives in the current year by the number of articles it publishes in that year, see Figure 1. According to the definition of *Im* and the *Im* window in Figure 1, we have $Im = K \cdot (C(1) - C(0))$, the meaning of

K is the same as that above, namely K=1. Combining Eq. 3, we obtain the formula of Im:

$$Im = \frac{T_1 \cdot (e^{\frac{\tau}{T_1}} - e^{-\frac{1-\tau}{T_1}})}{T_1 - T_s} - \frac{T_s (e^{\frac{\tau}{T_s}} - e^{-\frac{1-\tau}{T_s}})}{T_1 - T_s} \tag{8}$$

Eq. 8 describes the relation between Im and parameters T_s, T_1 and τ. When $\tau = 0.3$ year, we calculate graphs of Im disturbed by different average publication delay with different T_1 values (8, 10, 12, 14 years) in Figure 5. It is shown that the bigger increment the average publication delays in a scientific field, the more decrease of the immediacy indexes of journal in the field; the bigger the time constant T_1 of the aging process, the smaller the immediacy index.

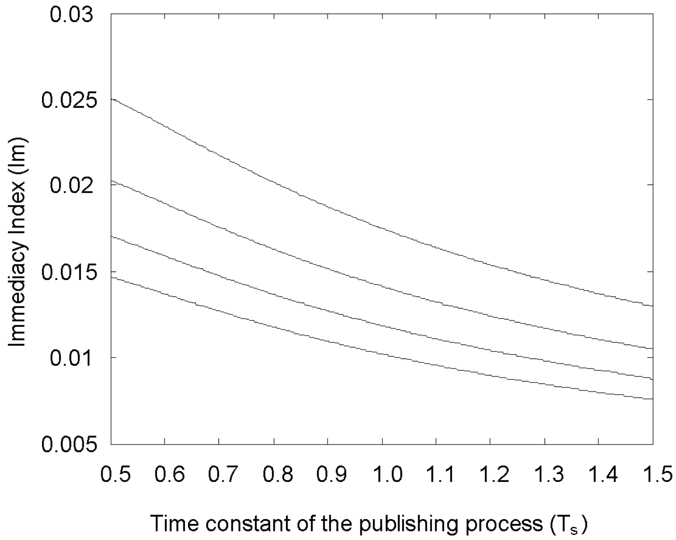

Figure 5. Graphs of Im vs T_s (T_1 = 8, 10, 12, 14 years, respectively, from top to bottom)

The cited half-life

The cited half-life is a measure of the rate of decline of the citation curve. It is the number of years that the number of current citations takes to decline to 50% of its initial value (the cited half-life is over 7.0 years in the example given in Figure 1). It is a measure of how long articles in a journal continue to be cited after publication (AMIN & MABE, 2000). According to the cumulative citation distribution Eq. 3, we can deduce the formula of the cited half-life of a journal in a science field. First let $C(T_{0.5}) = 0.5$, so $T_{0.5}$ satisfies the expression as follows:

$$1-\frac{T_1 \cdot e^{-\frac{T_{0.5}-\tau}{T_1}}}{T_1-T_s}+\frac{T_s \cdot e^{-\frac{T_{0.5}-\tau}{T_s}}}{T_1-T_s}=0.5 \qquad (9')$$

Predigesting Eq. 9', we have

$$T_1 \cdot e^{-\frac{T_{0.5}-\tau}{T_1}} - T_s \cdot e^{-\frac{T_{0.5}-\tau}{T_s}} = 0.5 \cdot (T_1 - T_s) \qquad (9)$$

$T_{0.5}$ is related with parameters τ, T_s and T_1. Let $\tau = 0.3$ year, using Eq. 9, we calculate graphs of $T_{0.5}$ disturbed by different publication delay parameter T_s with T_1 values (8, 10, 12, 14 years) in Figure 6. It is shown that the greater T_s or T_1 is, the longer $T_{0.5}$ would be.

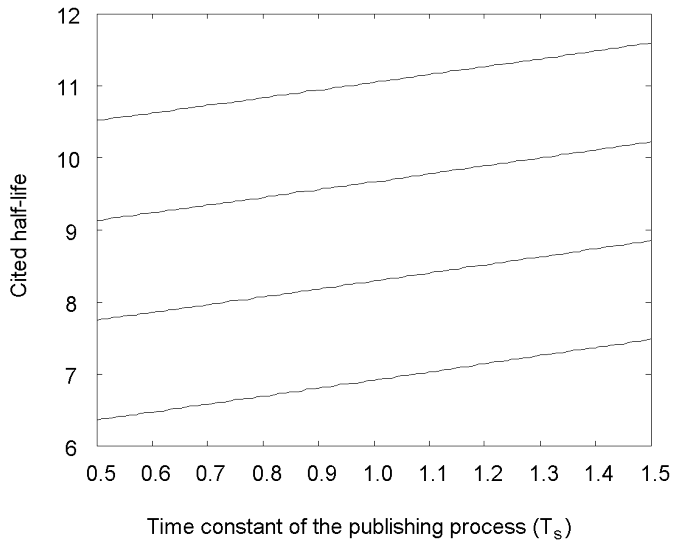

Figure 6. Graphs of $T_{0.5}$ vs T_s (T_1 = 8, 10, 12, 14 years, respectively, from top to bottom)

According to these calculated results, we obtain trend graphs of three indicators disturbed by the change of the average publication delay according to different time constant T_1 of aging process and some conclusions as follows:

1. When the average publication delay of the discipline increases; *IF*, *Im* and $f(T_{top})$ would decrease, $T_{0.5}$ and T_{top} would be prolonged.

2. When the pure delay τ of the discipline increases, *IF* and *Im* are decreased, $f(T_{top})$ is unchangeable, $T_{0.5}$ and T_{top} would be scale-up.
3. When T_1 is different, change rates of these indicators are different, namely the slope of per curve is different, but it cannot is judged. So we will study sensitivities of these indicators to parameters of the average publication delay using sensitivity theory according to different T_1.

Sensitivity analysis of three indicators

System sensitivity is a property that status variables of the system are affected by changes of some parameters (LUO, 1990). In this paper, we will theoretically analyze and study sensitivities of the three indicators to two parameters of the publication delay using the absolute sensitivity function.

Sensitivities of IF to publication delay parameters

We can deduce differential coefficients of *IF* to τ, T_s using Eq. 7 and obtain sensitivity functions of IF to two delay parameters as follows:

$$\frac{\partial IF}{\partial \tau}=\frac{(e^{-\frac{3-\tau}{T_s}}-e^{-\frac{3-\tau}{T_1}})-(e^{-\frac{1-\tau}{T_s}}-e^{-\frac{1-\tau}{T_1}})}{T_1-T_s} \tag{10}$$

$$\frac{\partial IF}{\partial T_s}=\frac{[(T_s-T_1)(1-\tau)-T_1T_s]\cdot e^{-\frac{1-\tau}{T_s}}-[(T_s-T_1)(3-\tau)-T_1T_s]\cdot e^{-\frac{3-\tau}{T_s}}+T_1T_s(e^{-\frac{1-\tau}{T_1}}-e^{-\frac{3-\tau}{T_1}})}{T_s(T_s-T_1)^2} \tag{11}$$

In Eq. 10 and Eq. 11, $\frac{\partial IF}{\partial \tau}$ is the sensitivity function of *IF* to τ, $\frac{\partial IF}{\partial T_s}$ is the sensitivity function of *IF* to T_s.

When $T_s = 1$ year and τ is altered from 0.2 to 0.5 year, graphs of the sensitivity of *IF* to τ with T_1 values are shown in Figure 7. When $\tau = 0.3$ year and T_s is altered from 0.5 to 1.5 year, graphs of the sensitivity of *IF* to T_s with T_1 values are shown in Figure 8; T_1 is increasing from top to bottom and altered from 8 to 15 years.

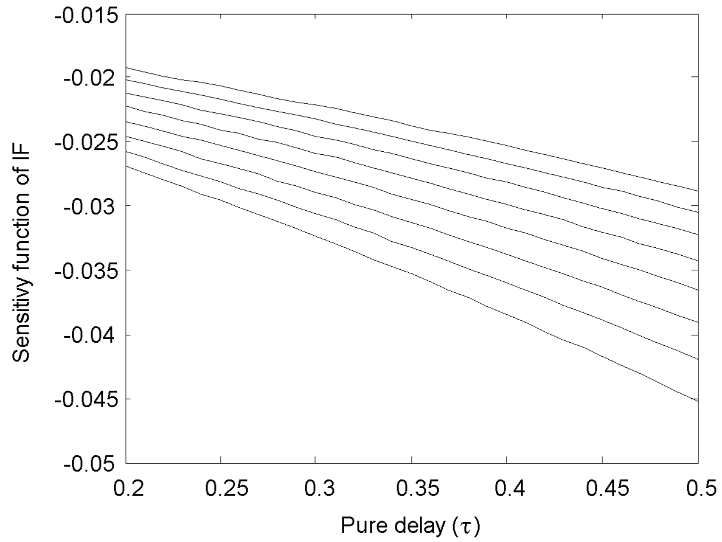

Figure 7. Graphs of the sensitivity function $\frac{\partial IF}{\partial \tau}$

(T_1 = 8, 9, 10, 11, 12, 13, 14, 15 years, respectively, from top to bottom)

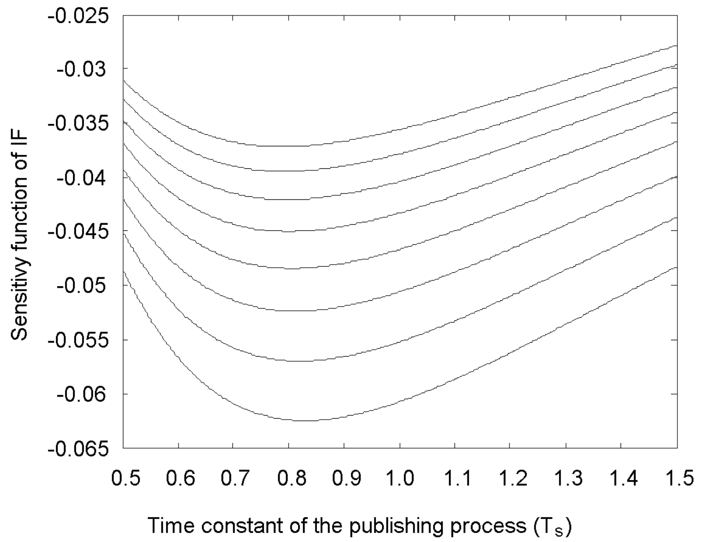

Figure 8. Graphs of the sensitivity function $\frac{\partial IF}{\partial T_s}$

(T_1 = 8, 9, 10, 11, 12, 13, 14, 15 years, respectively, from top to bottom)

According to results shown in Figure 7 and Figure 8, we can learn:

1. Because two sensitivity functions $\frac{\partial IF}{\partial \tau} < 0$, $\frac{\partial IF}{\partial T_s} < 0$, the impact factor would decrease along with increasing τ or T_s and the decreasing rate is different according the change of each parameter.
2. When T_1 is the constant, the absolute value of $\frac{\partial IF}{\partial \tau}$ would increase along with increasing τ. It is illuminated that the sensitivity of *IF* to τ adds along with increasing τ, namely the bigger the pure delay is, the more serious the influence of publication delays on *IF* would be. When $T_s < 0.82$, the absolute value of $\frac{\partial IF}{\partial T_s}$ is adding along with increasing T_s, but it would decrease along with increasing T_s when T_s keeps on adding.
3. The absolute value of $\frac{\partial IF}{\partial \tau}$ or $\frac{\partial IF}{\partial T_s}$ decreases along with increasing T_1, it is shown that a scientific discipline whose literature aging rate is faster has a more serious influence of the publication delay on journal's *IF*s than that whose literature aging rate is slow.

The sensitivity of Im to publication delay parameters

We can deduce differential coefficients of *Im* to τ, T_s using Eq. 8 and obtain sensitivity functions of *Im* to two delay parameters as follows:

$$\frac{\partial Im}{\partial \tau} = \frac{e^{\frac{\tau}{T_1}} - e^{-\frac{1-\tau}{T_1}} - e^{\frac{\tau}{T_s}} + e^{-\frac{1-\tau}{T_s}}}{T_1 - T_s} \tag{12}$$

$$\frac{\partial Im}{\partial T_s} = \frac{[\tau(T_1-T_s)-T_1T_s]\cdot e^{\frac{\tau}{T_s}} + [(1-\tau)(T_1-T_s)-T_1T_s]\cdot e^{-\frac{1-\tau}{T_s}} + T_1T_s(e^{\frac{\tau}{T_1}} - e^{-\frac{1-\tau}{T_1}})}{T_s(T_s-T_1)^2} \tag{13}$$

In Eq. 12 and Eq. 13, $\frac{\partial Im}{\partial \tau}$ is the sensitivity function of *Im* to τ, $\frac{\partial Im}{\partial T_s}$ is the sensitivity function of *Im* to T_s.

When $T_s = 1$ year and τ is altered from 0.2 to 0.5 year, graphs of $\frac{\partial Im}{\partial \tau}$ with T_1 values are shown in Figure 9. When $\tau = 0.3$ year and T_s is altered from 0.5 to 1.5 year, graphs of $\frac{\partial Im}{\partial T_s}$ with T_1 values are shown in Figure 10. T_1 is increasing from top to bottom and altered from 8 to 15 years.

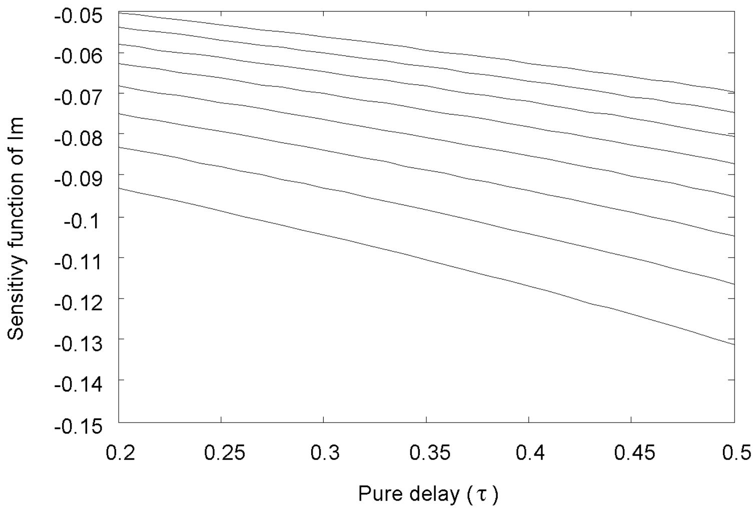

Figure 9. Graphs of the sensitivity function of $\frac{\partial Im}{\partial \tau}$

(T_1 = 8, 9, 10, 11, 12, 13, 14, 15 years, respectively, from top to bottom)

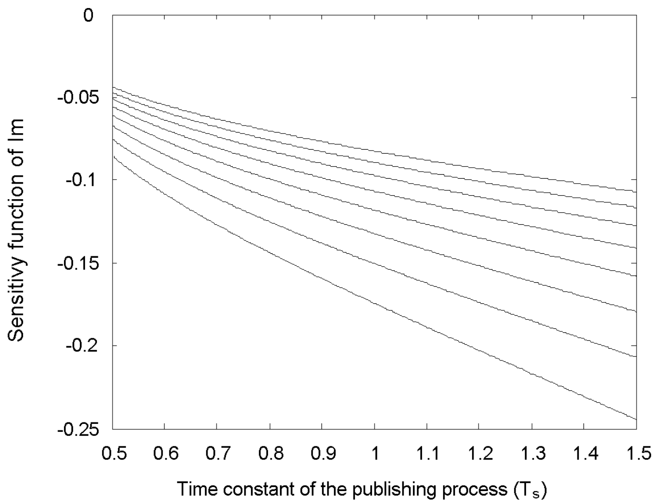

Figure 10. Graphs of the sensitivity function of $\frac{\partial Im}{\partial T_s}$

(T_1 = 8, 9, 10, 11, 12, 13, 14, 15 years, respectively, from top to bottom)

From Figure 9 and Figure 10, we can learn:

1) Because two sensitivity functions $\frac{\partial Im}{\partial \tau} < 0$ and $\frac{\partial Im}{\partial T_s} < 0$, the immediacy index would decrease along with increasing τ or T_s and the decreasing rate is different according the change of each parameter.

2) When T_1 is a constant, two sensitivity functions $\frac{\partial Im}{\partial \tau}$ and $\frac{\partial Im}{\partial T_s}$ of the immediacy index would decrease along with increasing τ or T_s, and the decreasing rate would be adding along with increasing τ or T_s.

3) The bigger T_1 is, the smaller the absolute value of $\frac{\partial Im}{\partial \tau}$ or $\frac{\partial Im}{\partial T_s}$ would be; namely the slower the development of a science discipline, the less the influence of the publication delay on it.

The sensitivity of the cited half-life to publication delay parameters

Because the cited half-life $T_{0.5}$ is satisfied with Eq. 9, differential coefficients of $T_{0.5}$ to τ and T_s can be deduced using the method solving differential coefficients of a hidden function, and two sensitivity functions of $T_{0.5}$ are obtained:

$$\frac{\partial T_{0.5}}{\partial \tau} = 1 \tag{14}$$

$$\frac{\partial T_{0.5}}{\partial T_s} = \frac{\left(\frac{\tau - T_{0.5} - T_s}{T_s}\right) \cdot e^{-\frac{T_{0.5}-\tau}{Ts}} + 0.5}{e^{-\frac{T_{0.5}-\tau}{T_1}} - e^{-\frac{T_{0.5}-\tau}{T_s}}} \tag{15}$$

In Eq. 14 and Eq. 15, $\frac{\partial T_{0.5}}{\partial \tau}$ is the sensitivity of $T_{0.5}$ to τ, $\frac{\partial T_{0.5}}{\partial T_s}$ is the sensitivity of $T_{0.5}$ to T_s. According to Eq. 14, the sensitivity of $T_{0.5}$ to τ is always 1, namely $T_{0.5}$ has a direct proportion relation with τ, namely $T_{0.5}$ would be proportionally added along with increasing the pure delay.

When $\tau = 0.3$ year and T_s is altered from 0.5 to 1.3 year, graphs of the sensitivity $\frac{\partial T_{0.5}}{\partial T_s}$ with different T_1 values are shown in Figure 11. T_1 is increasing from top to bottom and altered from 8 to 12 years. So we can obtain some conclusions as follows:

1) Because the sensitivity functions $\frac{\partial T_{0.5}}{\partial T_s} > 0$ and $\frac{\partial T_{0.5}}{\partial \tau} = 1$, $T_{0.5}$ is adding along with increasing T_s and τ when T_1 is a constant.

2) When T_1 is a constant and T_s is increasing, the cited half-life would be prolonged and the increasing rate is adding. The bigger T_1, the less the influence of the publication delay on $T_{0.5}$.

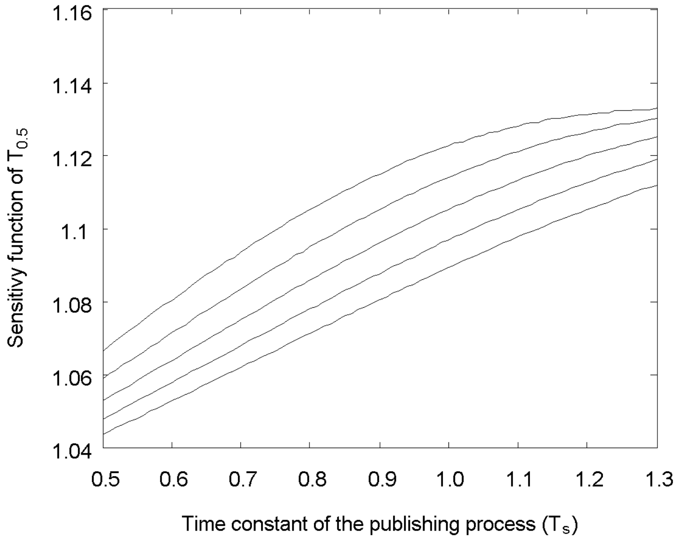

Figure 11. Graphs of the sensitivity function $\frac{\partial T_{0.5}}{\partial T_s}$

(T_1 = 8, 10, 12, 14 years, respectively, from top to bottom)

Conclusions

Based on the analytical expression of the disturbed citation distribution and some theoretical hypotheses, formulae of Impact Factor, Immediaty Index and Cited Half-Life are established. These formulae illuminate the relations of these indicators between publication delay parameters. Using the parameter sensitivity analysis, it is found that these influences of publication delay parameters (T_s and τ) on the three indicators are different according to different time constant T_1 of the aging process. Some conclusions are as follows:

1. When the pure delay or the time constant T_s of a science discipline is added, namely the average publication delay is added too, and other conditions are unchangeable, the Impact Factor and Immediaty Index of a journal in the science discipline are decreased and the decreasing rate is increasing.
2. The Cited Half-Life and the peak age of the citation distribution of the journal are being prolonged along with increasing the average publication delay of the science discipline.
3. Results of the parameter sensitivity analysis are that the influence of publication delay parameters on scientific journals is different when the aging process is different; and the slower the aging rate of the science discipline, the more insensitive the responses of the influences of publication delay parameters on the three indicators; the faster the aging rate of the science discipline, the more sensitive the responses of that. So editors of those journals of the discipline with faster development rate should decrease publication delays to the best of their abilities, otherwise spread and transform of scientific research productions would be baffled.
4. Actually, the ISI three indicators may be influenced by some factors, including a number of articles published by this journal in a given period of time, the scientific field to which the journal belongs, the journal's self-citation rate, the language of published articles, publication delays of the journal and journals citing the journal, etc.; the publication delay is one of these factors. So it is exists that the prestigious and also high-impact journals are often the ones with long publication delays. The implications of the work more extensively or also for particular cases are complicated and will be studied carefully in our succeeding works.

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