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Constructing a new patent bibliometric performance measure by using modified citation rate analyses with dynamic backward citation windows

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Abstract The objective of this research is to develop a new patent bibliometric performance measure by using modified citation rate analyses with dynamic backward citation windows. Cited half-life employed in bibliometrics was adopted in order to establish a model of annual patent backward citation windows. Based on the dynamic behavior of backward citation windows, the annual backward patent citation rates for each technology domain can be calculated to measure its bibliometric performance. It was found that the dynamic backward citation window represents more accurately the citation cycle time which is a key factor on technology assessment. Because different technology domain may have disparate attributes, a normalized backward citation rate was developed to measure the corresponding rank for each domain respect to the entire industry. Three technology domains were then chosen for demonstrative case studies which represent semiconductor, LCD, and drug industries.

Keywords Patent bibliometric performance measure · Dynamic backward citation window · Cited half-life · Citation rate analysis

Introduction

Patent information is an important source for scientific and technological knowledge. More than 90% of patent specifications came from research and development (R&D) results and about 80% of which never appears in formal publications. The World Intellectual Property

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Organization (WIPO) found that effective use of patent information can greatly shorten R&D time up to 60% and can save R&D costs up to 40%. Information from patent documents not only stimulates new research directions but also promotes new usages of current technologies. Furthermore, patent analyses can reveal or predict corporate competitiveness, technology life cycle, and industrial growth. As Gay and Le Bas (2005) summarized, patent citations can be used to: (1) assess the value of technological inventions; (2) identify the origins, or the "knowledge base," of inventions; and (3) detect and predict technological knowledge flows.

In the world of scientific journals, researchers publish their research results in journals in the hope that their findings and ideas will influence further studies in related areas. Citations represent a form of evidence suggesting research influences. As such, Garfield (1972) proposed an index of Impact Factor (IF), which was then chosen by Science Citation Index (SCI) in 1960 as a mean to specify the influence—and by extension, the value—of the indexed journals (Andrew 2003). The IF indicator determines the annual impact of a journal by using the number of its backward citations from the chosen year to the previous 2 years divided by the total number of the papers. More specifically, the formula for calculating current IF is shown below:

$$\mathrm{IF}_t^j = \frac{C_{t,t-1}^j + C_{t,t-2}^j}{P_{t-1}^j + P_{t-2}^j} \tag{1}$$

where IF_t^j represents the Impact Factor of journal j at year t; $C_{t,t-1}^j$ and $C_{t,t-2}^j$ represent the numbers of backward citations to papers published at journal j in year $t-1$ and year $t-2$ by all papers published in year t; P_{t-1}^j and P_{t-2}^j represent the total numbers of papers published by journal j in year $t-1$ and $t-2$.

Impact Factor is a well-accepted index for evaluating the current impact of a journal. A journal with a higher IF in a specific year is usually regarded as having more impact than other journals in that year. However, Dong et al. (2005) have stated two major problems of IF. First, the index uses a fixed backward citation window (2 years), which is arbitrary in determining the impact of a journal. Second, it does not hold for cross-field journal evaluation. Bibliometric scholars have tried to improve its applicability by appending to or reformulating the index (Amin and Mabe 2003). Asai (1981) tried to count and assign weightings to backward citations in the past 4 years. Van Leeuwen and Moed (2002) suggested that, depending on the nature of various academic fields, backward citation window periods should be extended to four or 5 years. Sombatsompop et al. (2004) used cited half-life to determine the appropriate backward citation window length for IF. Pudovkin and Garfield (2004) proposed "rank-normalized IF (rnIF)" and Sombatsompop et al. (2004) proposed "Median Impact Factor (MIF)" to normalize the journal rankings. Ramirez et al. (2000) proposed a renormalized IF (F_c), which enables direct comparisons across journals of different categories. Similarly, Van Leeuwen and Moed (2002) attempted to fix the comparability problems resulted from disciplinary differences. Sombatsompop and Markpin (2005) proposed an "Impact Factor Point Average (IFPA)" index to normalize the differences among journals.

Backward citations are also used in the world of patents for impact analyses, which aim to identify trends and competitions in technology development in order to better deploy resources and investment. Patent analyses often employ indices developed by the CHI Research Inc. (2001), such as the Number of Patents (NP), Cites per Patent (CP), Current Impact Index (CII), Technology Strength (TS), Technology Cycle Time (TCT), Science Linkage (SL), Science Strength (SS), and so on. Among them, the Current Impact Index

(CII) developed by Narin and Hamilton is analogous to IF in journal bibliometric evaluation (Narin and Hamilton 1996). CII was originally defined as the number of times a company's (or a technology area's) patents of the previous 5 years get cited in a particular year divided by the average number of backward citations to all of its patents in that same year. It indicates the impact or quality of a company's (technology area's) patents based on citing from current year to the past 5 years. The expected value of CII for the entire patent system is 1. The CII of a company (technology area) can be calculated by:

$$CII_t^j = \frac{\sum_{i=1}^{5} P_{t-i}^j \frac{C_{t,t-i}^j / P_{t-i}^j}{C_{t,t-i} / P_{t-i}}}{\sum_{i=1}^{5} P_{t-i}^j} \tag{2}$$

where CII_t^j represents the Current Impact Index of company (technology area) j at year t; $C_{t,t-i}^j$ represents the numbers of backward citations to patents granted to company (technology area) j in year $t - i$ by all patents granted in year t; P_{t-i}^j represents the total numbers of patents granted to company (technology area) j in year $t - i$; $C_{t,t-i}$ represents the numbers of backward citations to all patents granted in year $t - i$ by all patents granted in year t; P_{t-i} represents the total numbers of patents granted in year $t - i$.

A technology area with a higher patent backward citation rate suggests that it has higher technology impact to the entire industry (Breitzman and Narin 2001). CII and IF are both performance indices using fixed backward citation windows. CII uses a backward citation window of 5 years, and IF uses 2 years. CII applies a weighted sum of citation ratios for the 5-year period, whereas IF calculates a ratio between total citations and total number of papers in the 2-year period. On the other hand, TCT is the median age of the cited patents within a specific domain, and indicates the pace of technology changes. Narin (1993) showed how TCT values may differ from industry to industry; in a fast changing area such as electronics, the cycle time may be as short as three to 5 years, whereas in some of the very old technologies such a ship and boat building, the cycle time may range from 15 to 20 years.

The level of patent analysis varies depending on the scale and the purposes of investigation. For example, an enterprise-level analysis may attempt to assess a company's performance of a company in different industries, say, Samsung's performance in semiconductor and LCD industries. By so doing a company may be able to better assess its investment and derive better business and technology development strategies. Patent analyses can also be conducted at industry or country levels or in combinations to reveal strengths and weaknesses. For example, investigators may compare the patent performances of several industries in order to assess their relative technology impact. Alternatively, investigators may also compare the patent performances of leading companies representing different industries such as the Taiwan Semiconductor Manufacturing Company (TSMC) for the semiconductor industry and Ford for the car industry. In cross industry comparisons, however, investigators encounter problems from CII's use of a fixed backward citation window on the one hand, and the domain differences represented by TCT on the other. It seems arbitrary to use a fixed backward citation window based indicator to evaluate the patent performances of different technology domains, and the use may mislead comparisons. An index that takes into account domain differences is required for the more complex patent analyses.

This paper introduces the concept of a dynamic backward citation window for better assessment of a technology domain's patent impact. The dynamic backward citation window is based on rigorous patent citation rate analyses of a particular technology field and thus is more accurate than a fixed window. In additions, a normalized patent backward citation rate was established in order to compare the patent performances of different specific domains in the entire industry. To test the applicability of the proposed ideas this study has conducted patent citation rate analyses using dynamic backward citation windows in three technology domains: the semiconductor, LCD, and the drug industry. The results suggest the superiority of the dynamic backward citation window over the fixed backward citation window.

Backward citation windows in patents

Researchers and R&D staff often want to find out the immediate impact of patents granted in the current year so that they can allocate limited resources to the more promising technologies. Rapid progress in technologies, however, has changed the technology life cycles in different domains and consequently raises the problem of appropriate backward citation windows for patent analyses. This paper argues for the use of a dynamic, domain-specific backward citation windows instead of a fixed window, which may unfavorably affect the assessments in certain technology domains.

The backward citation rate of a science journal is not steady; an article's backward citation rate usually declines after passing its half-life (Berton and Kebler 1960). Models for observing the decline of citations exist, such as Griffith (1988) literature aging model that calculates a journal's annual usage backwards from the current year. The concept of the cited half life (CHL) is used to measure the decline rate of a journal's citation curve and how long each journal article continues to be cited after it is published (Amin and Mabe 2003). For each journal, the speed of reaching the CHL reflects its citation cycle. A journal reaching CHL faster means it has a shorter citation cycle and a shorter impact period. A basic science journal might have a longer CHL than an applied science/technology journal whose content can get outdated faster (Ladwig and Sommese 2005). CHL helps to differentiate the immediate and long term impacts of journals. CHL also offers clues about a journal's conditions; for example, dramatic changes in a journal's CHL may suggest changes in the journal's editorial policies. The concept of CHL is illustrated in Fig. 1.

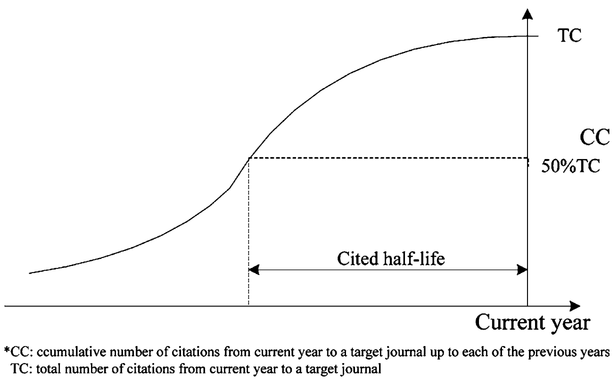


Fig. 1 A typical model of an accumulative backward citation curve

The concept of CHL can be applied to patent bibliometric analyses as well. CHL is then used to determine the annual patent backward citation window (CW) for a specific technology domain so that the current impact of its patents can be appropriately evaluated. A longer CW in a specific technology domain means that patents in this domain have a longer impact period. As one can imagine, patent backward citation windows for different technology domains can hardly be the same because of different backward citation patterns, patent contents, and importance. CW also helps to differentiate patent impact of various sub-domains under a larger parent domain; backward citation windows for a subdomain (CW^a) and for the parent domain (CW^A) can be calculated and compared.

Annual patent backward citation windows—case studies

This research used patent information in three technology domains—the semiconductor, LCD, and drug industries—to demonstrate the applicability of the annual backward citation windows in patent bibliometric evaluation. The subject coverage of each domain is defined by the United States Patent and Trademark Office (USPTO)'s patent classification schedule. Patent data from the USPTO database for the period between 1986 and 2006 were used for the analyses.

The first domain, semiconductor industry, is enormous in scale and scope. Technologies developed in this domain have been widely transferred into other industries. The semiconductor domain is best defined (Weinstein and Huang 1999) as comprising the USPTO Class 257 ("Active solid-state devices, e.g., transistors, solid-state diodes"), Class 365 ("Static information storage and retrieval"), and Class 438 ("Semiconductor device manufacturing: process"). The numbers of patents in semiconductor industry and their annual backward citations from 2006 back to 1986 are shown as in Fig. 2a.

Similar to the semiconductor domain, the LCD industry is populated with a variety of technologies and therefore is difficult to get a clear definition. This research followed the definition in Stolpe (2002) and classified the LCD domain as comprising the USPTO Class 349 ("Liquid crystal cells, elements and systems"). The numbers of patents in LCD industry and their annual backward citations from 2006 between 1986 and 2006 are shown as in Fig. 2b.

The drug industry is highly related to the biotechnological industry. This paper adopts the definition by Lichtenberg and Virabhak (2002) and defines the drug domain as comprising the USPTO Class 424 ("Drug, bio-affecting and body treating compositions"). The numbers of patents in drug industry and their annual backward citations from 2006 between 1986 and 2006 are shown as in Fig. 2c.

Data show that the numbers of patents in these three domains are in similar patterns; numbers increase from 1986 to 2006. The values of CHL for these three domains were calculated and listed in Table 1. One can see that both the CHL for each domain and the CHL for the overall industry increased and have been changing dramatically year by year as shown in Fig. 3. Furthermore, most of the CHL in Table 1 are greater than 5 years, which support our argument that the frequently used fixed backward citation window of 5 years in previous patent analyses is improper and biased. The prolonged CHL means that the impact period of patents is becoming longer. However, as one can observe from Table 1, except in the year of 1986, the CHL of the semiconductor and LCD domains are all lower than those of the drug domain and those of the overall industry covered in USPTO patent system. It suggests that the use of a fixed CW may underestimate the current

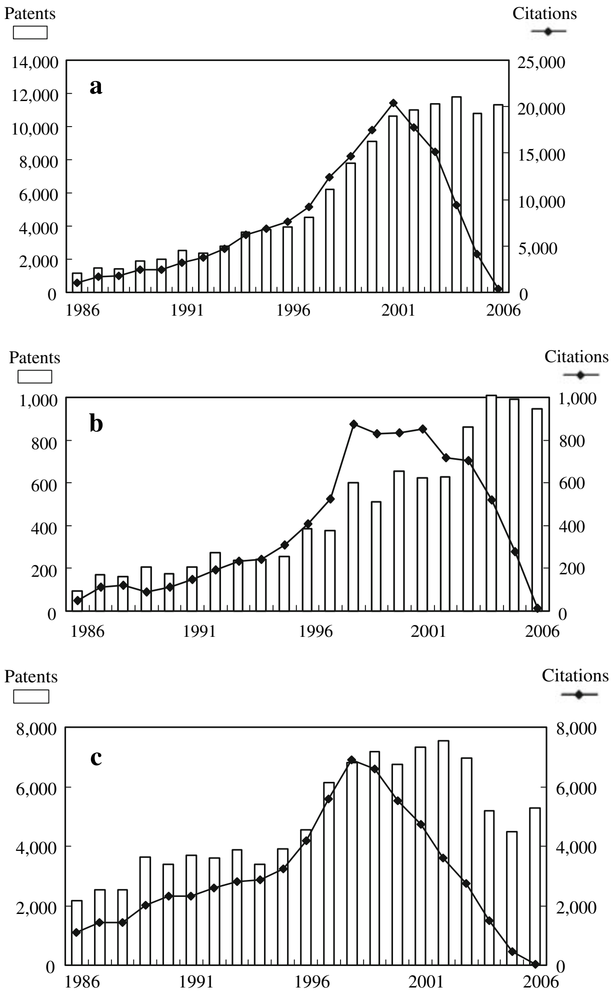


Fig. 2 **a** Patent numbers and backward citations from 2006 for the semiconductor industry. **b** Patent numbers and backward citations from 2006 for the LCD industry. **c** Patent numbers and backward citations from 2006 for the drug industry

impact of patents in a certain domain. Our use of the dynamic CW is more indicative of the real patent impact of each individual domain.

By rounding up the annual CHL values of each domain to the nearest integers, this study determines the lengths of the annual patent CW for the three domains. As Fig. 4 shows, the patent backward citation window for each domain has been changing consistently over the years. Although there are ups and downs in the domains of semiconductor and LCD, the backward citation windows for all domains have exceeded 5 years after the year of 2002.

In terms of each specific domain, the annual CW for the semiconductor industry between 1988 and 2001 was stable and consistent with the five-year fixed CW used in traditional patent citation analyses. But since 2001 annual CW has lengthened and become more than 5 years. The prolonged CW may be explained by the increasing popularity of the semiconductor industry in recent years and the heavier entrepreneur involvement from different parties. The expanding CW after 2001 means that semiconductor patents now have a longer impact period, and the use of the fixed CW will seriously underestimate the real impact.

Table 1 Values of CHL for semiconductor, LCD, drug, and all industries

	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06
Semi- conductor	5.8	5.5	5.3	5.1	4.6	4.6	4.8	4.6	4.9	5.1	5.3	5.5	5.2	5.3	5.3	5.3	5.6	5.8	6.2	6.4	6.9
LCD	5.7	4.4	4.3	4.6	4.3	4.3	5.0	5.3	5.5	6.1	5.8	6.3	6.3	6.3	6.0	5.9	5.8	5.8	6.6	7.2	8.0
Drug	5.3	5.8	5.7	5.9	5.9	6.1	6.0	5.9	6.1	6.6	6.9	7.7	7.8	7.8	7.8	7.8	7.6	7.8	8.1	8.6	9.0
All industries	5.4	5.7	5.6	5.8	5.9	6.0	6.1	6.3	6.5	6.7	7.0	7.3	7.3	7.4	7.3	7.4	7.4	7.5	7.7	8.0	8.5

Fig. 3 Values of CHL for semiconductor, LCD, drug, and all industries

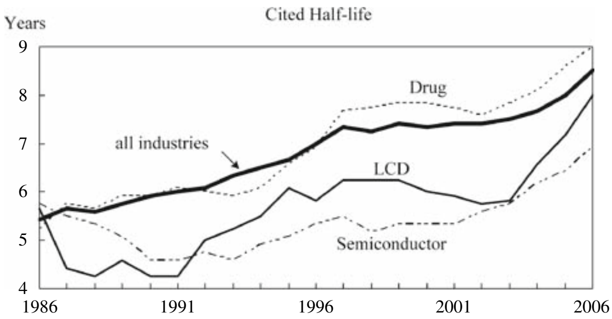
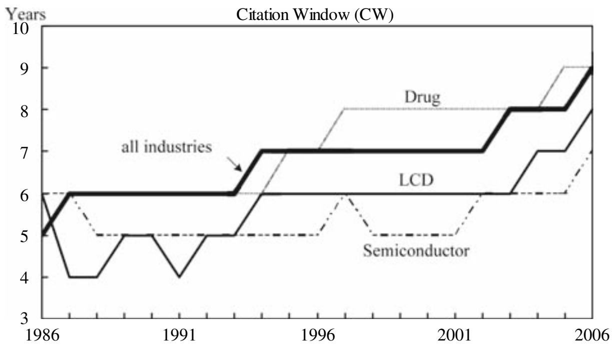


Fig. 4 Annual patent backward citation windows for semiconductor, LCD, drug, and all industries



In the LCD domain, the annual CW lengthened greatly between 1991 and 1994 and again between 2003 and 2006. This suggests the prominence of the LCD technology in the early 90s; and the mid-2000s saw another wave of intensive growth. The two discernible booming stages in the LCD development history also suggest the weakness of using the fixed CW in patent analyses. The LCD domain, like the semiconductor industry, suffers from an underestimation in patent impact when the fixed CW is used.

The drug industry has had the longest annual CW among the three domains since 1997. The growth of the drug domain in terms of its annual patent CW shows a similar trend with the entire industries. This suggests the impact of drug patents have prolonged after 1997. Further, this domain's patents probably have a longer impact period than the average. In general, the annual CW of the drug domain has been relatively stable and has grown smoothly over years. The noticeable stretching of drug patents CW in the mid-90s may be explained by the society's growing concerns of health care and the popularity of anti-aging technologies. Of the three domains, the drug industry suffers most from the underestimation of patent impact assessment based on fixed CW.

The uses of the traditional fixed CW (5 years) and the dynamic CW (domain-specific annual CW) proposed in this paper result in different sample data in terms of annual patents and backward citations for patent impact analyses. For example, as one can see in Table 2, in the semiconductor domain, the number of USPTO patents granted within 5 years prior to 1987 was 4578 by using the traditional fixed CW (5 years), and the number of backward citations to those patents from 1987 was 3923. However, when the dynamic CW is used, the backward citation window for the semiconductor domain is six year for 1987. And the number of patents (granted within 6 years before 1987) becomes 5329—an increase by 16%; the total backward citations from 1987 becomes 4482 (increased by

Table 2 Sample sizes by fixed CW and dynamic CW for 1987 and 2006

		Number of patents granted within CW		Citations to patents granted Within CW from current year	
		Fixed CW (CW = 5)	Dynamic CW	Fixed CW (CW = 5)	Dynamic CW
	Semiconductor	4578	5323 (CW = 6)	3923	4482 (CW = 6)
T = 1987	LCD	370	347 (CW = 4)	520	479 (CW = 4)
	Drug	9980	11997 (CW = 6)	3646	4414 (CW = 6)
	Semiconductor	55586	72503 (CW = 7)	66808	98966 (CW = 7)
T = 2006	LCD	4109	5872 (CW = 8)	3073	5612 (CW = 8)
	Drug	31537	58417 (CW = 9)	13089	37695 (CW = 9)

14%). Similarly, within the fixed CW from 2006 the number of semiconductor patents granted was 55586, and the number of backward citations was 66808. When the dynamic CW was used, the patent number becomes 66808 (increased by more than 30%), and the backward citation number becomes 98966 (increased by about 50%). It is considered that the samples based on the dynamic CW model were more realistic and representative for assessing technology impact of those patents.

Impact of the dynamic backward citation window

To further demonstrate the impact of using dynamic backward citation window in patent bibliometric analyses, patents of a sub-domain under the semiconductor domain, which include all the semiconductor patents granted to Taiwan companies and their corresponding backward citations for the past 20 years, were analyzed based on dynamic annual backward citation windows. USPTO classifies the patents of this sub-domain as Class 257, Class 365, or Class 438. The annual dynamic citation windows were listed in Table 3 and depicted in Fig. 5. The annual backward citation windows for Taiwan were shorter than those for the world, but the numbers ascended noticeably. This suggests that Taiwan's semiconductor industry was fast growing, although its growth was still somewhat behind the global growth of the industry. Comparing the two curves in Fig. 5, Taiwan's semiconductor industry was clearly in significant rise and may soon approach stability parallel to the global semiconductor industry. On the other hand, semiconductor industry in World may be close to the end of its Stable phase and may start its descending phase in which fewer new granted patents and citations cause its citation window to lengthen again.

Citation rate analysis with dynamic backward citation windows

Once the durations of the annual patent CW for each domain are determined, the evaluation of patent bibliometric performance can be executed by calculating the backward Citation Rate (CR) of each domain and the parent domain based on their respective backward windows. Dynamic CW based CR analyses are more reasonable than the traditional fixed CW based analyses because the former is based on sufficient citation data. For example, as the previous section has shown, in the semiconductor domain for the year

Table 3 Annual backward citation windows for semiconductor domain

	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06
World	6	6	5	5	5	5	5	5	5	5	5	6	5	5	5	5	6	6	6	6	7
Taiwan	0	0	1	0	2	2	3	2	2	2	2	3	3	3	3	3	4	4	5	5	6

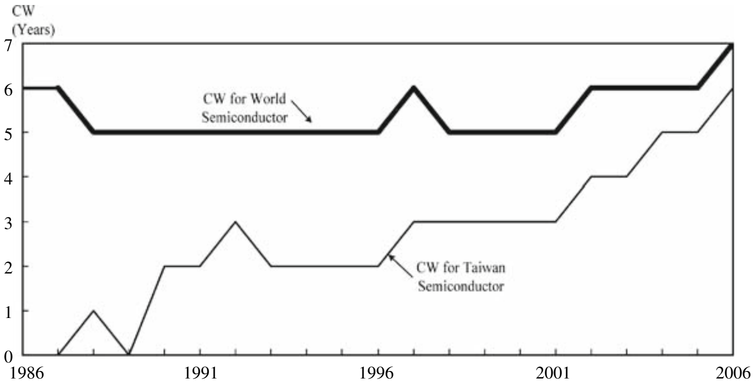


Fig. 5 Annual patent backward citation windows for semiconductor in world and Taiwan

of 2006, the patents covered in fixed CW sample reflect only 76.67% of the patents covered in the dynamic CW sample (55586:72503). The numbers derived from the use of annual patent CW are more representative of the real world patent performances because the dynamic CW is determined by the actual annual CHL of each domain.

The current citation rate is based on the average number of backward citations throughout the dynamic citation window retrospectively from current year. It is calculated by dividing the sum of backward citations from current year to patents granted in previous years within the dynamic backward citation window by the total number of patents granted in the same period. It differs from CII in that yearly backward citation ratios were calculated before a weighted sum was produced. A higher backward citation rate indicates that patents of a specific domain are highly noticed and widely applied than those of other domains. The backward citation rate of Group *k*, which may be a specific domain *a* or its parent domain *A*, is shown as:

$$\mathrm{CR}^k = \sum_{i=1}^{CW^k} C^k_{t,t-i} \Bigg/ \sum_{i=1}^{CW^k} P^k_{t-i} \tag{3}$$

where $C^k_{t,t-i}$ is the number of total backward citations occurring in the year t to those patents granted in year $t-i$; P^k_{t-i} is the number of patents granted in year $t-i$; CW^{k} is the dynamic backward citation window of Group k.

Figure 6a shows that, in the semiconductor domain, the patent backward citation rates promptly increased after 1996. This reflects a most intensive and rapid growth of the industry between 1996 and 2001. The backward citation rates began to decrease after 2001, suggesting a less significant impact and a decelerating growth as opposed to the previous stage. Here we would draw a comparison between our findings and Allan (2001) propositions on semiconductor business cycles. Allan, based on his observation of six business cycles in the semiconductor industry between 1965 and 1995, contended that each cycle was 5 years in average. Our findings suggest that Allan's propositions were largely true except in the years of 2002–2006. We were able to identify four semiconductor business cycles from 1986 to 2006, including: 1986–1991, the dynamic stage; 1992–1996, the steady stage; 1996–2001, the booming stage; and 2002–2006 the declining stage. The first three stages conformed to Allan's proposition of five-year cycle, but the fourth stage obviously showed difference. Before 2001 the backward citation rates based on either the fixed CW (5 years) or dynamic CW were almost the same because the dynamic CW for those years was very close to 5 years. However, after 2001 the dynamic CW increased noticeably, and therefore the fixed CW based backward citation rates actually underestimated the real citation impact and failed to represent the realistic development of the semiconductor industry after 2001.

Figure 6b shows the patent backward citation rates of the LCD domain. As one can observe from the figure, over years the backward citation rates of this domain have been fluctuating intensively within a short period of time. This seems to conform to the common perceptions of the LCD industry being a sunrise industry, which is still in a less stable stage as opposed to the relatively mature semiconductor industry. However, starting from 2000 the backward citation rates have declined, which may suggest that the LCD patents of the recent years have moved from the invention type to the application type. Similar to the semiconductor domain, the fixed CW based backward citation rates used to represent the LCD domain's patent impact very well between 1986 and 1994; during that period the backward citation rates based on either the fixed CW or the dynamic CW were nearly the same. But the gaps gradually widened since 1995. This means that the assessment of recent LCD patent impact can suffer from the underestimation of the fixed CW because, as one can see, the dynamic CW based backward citation rates since 2002 have become obviously higher than the fixed CW ones.

Figure 6c shows the situations in the drug domain. As one can see, the backward citation rates of this domain have been significantly lower than the other two domains; in fact, they have been lower than the average rates of the overall industries. Drug patents cite other patents way less than the other domain's patents. This suggests the relationships between drug patents are perhaps not as close as in domains like semiconductor or LCD. For this domain, the fixed CW based backward citation rates were fairly consistent with the dynamic CW based citation rates for the years of 1986–1989. Starting from 1990 the gaps between the two sets of backward citation rates have significantly widened. After 1990, using fixed CW in drug patents analyses would seriously underestimate patent impact because the dynamic CW has greatly increased and far exceeded 5 years.

Citation rate analysis across different domains

The previous section introduces the calculation of annual backward citation rates for each technology domain using the dynamic CW, or denoted as CR^a. The annual CR^a values are logically and meaningfully comparable within each domain because the annual patent CW is based on the annual CHL value. However, it is also necessary to derive a baseline to which CR^a values of different domains can be meaningfully compared. We use the annual CHL values of the entire industry—namely, the "parent domain"—to derive the annual parent domain CW. Cross domain comparisons become viable by using the normalized Citation Rate (nCR), which is the backward citation rate of a specific domain (CR^a) divided by the backward citation rate of the parent domain (CR^A). The normalized citation rate can be formulated as:

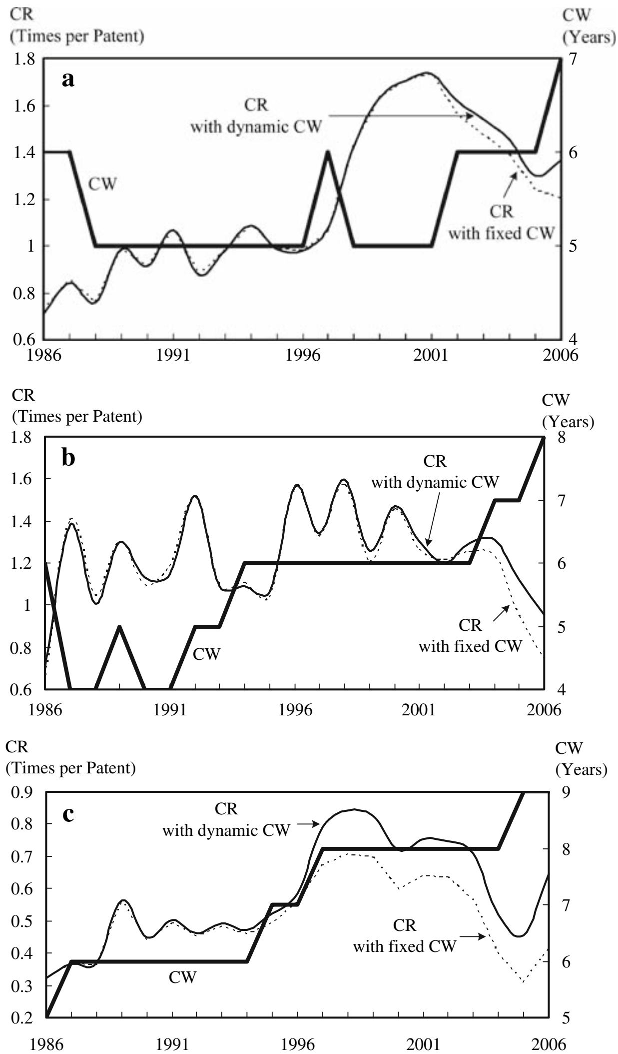


Fig. 6 **a** Patent backward citation rates of the semiconductor domain. **b** Patent backward citation rates of the LCD domain. **c** Patent backward citation rates of the drug domain

$$nCR^a = CR^a / CR^A \tag{4}$$

The nCR provides a basis on which different domains within a larger parent domain can be compared. The nCR values of a specific domain indicate its patent impact as compared to the average impact of the entire parent domain. For example, if the nCR value of a domain is above 1.0, it means that the technology impact of the domain is relatively higher than the average. The nCR values of the three domains in this study are listed in Table 4 and are illustrated as in Fig. 7. As can be clearly seen in Fig. 7, the nCR values of both the semiconductor and LCD domains are above the average of the parent domain (all USPTO included industries), while the values for the drug domain are nearly all below the average.

Table 4 Normalized citation rates for the semiconductor, LCD, and drug domains

	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06
Semi-conductor	1.8	1.8	1.6	1.7	1.7	1.9	1.5	1.7	1.7	1.5	1.4	1.5	1.5	1.8	1.8	1.7	1.6	1.5	1.5	1.6	1.4
LCD	1.8	2.9	2.2	2.2	2.1	2.0	2.6	1.8	1.7	1.6	2.2	1.9	1.7	1.4	1.5	1.3	1.2	1.3	1.4	1.3	1.0
Drug	0.8	0.8	0.8	1.0	0.8	0.9	0.8	0.8	0.8	0.8	0.8	1.1	0.9	0.9	0.7	0.7	0.8	0.7	0.5	0.5	0.7

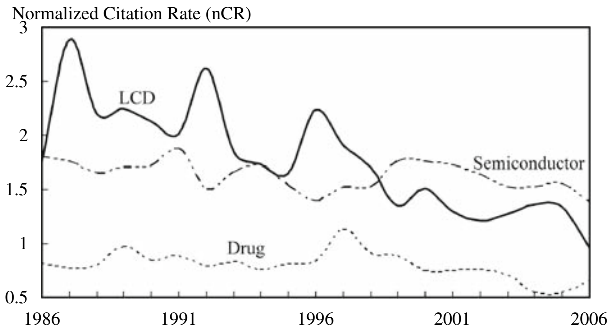


Fig. 7 Normalized citation rates of the semiconductor, LCD, and drug domains

Moreover, while the nCR of the semiconductor and the LCD domains both fluctuates, the LCD domain shows an obvious decline in nCR values in recent years. In contrast, the nCR of the drug domain has been relatively stable despite of its below-average values.

The fact that the nCR of the semiconductor domain is higher than those of the other domains indicates that semiconductor is by comparison a more active industry. On the other hand, the domain also shows a steadier trend in nCR, and the growth is similar to that of the entire parent domain (all industries). This suggests that semiconductor is becoming a mature industry. In the domain of LCD industry, the declining nCR may have reflected the relative maturity of the industry on the one hand, and a need for new innovations in LCD technologies on the other. The decreasing backward citation rates of LCD patents possibly suggest lowering patent quality in that domain or dissolving relationships between the LCD industry and the others. The nCR of drug industry is lower than the average industry and is the lowest among the three domains in this study. Factors contributing to the lower impact of drug patents may have also included legal constraints and other barriers imposed on drug patents.

Furthermore, the nCR trend for LCD industry fluctuates more than the other two industries and the average of all industries. This reflects the intensive competition and rapidly changing environment in flat panel display industry which is complicated both in their products and processes and usually require newly developed technologies from different technological domain.

Conclusions

In this paper we have introduced the use of the dynamic backward citation window (CW) to replace the traditional fixed backward citation window in patent citation analyses. For each technology domain, we used the Cited Half Life (CHL) to derive its annual patent CW and applied them in backward citation rate (CR) analyses. The new patent bibliometric measure was developed in order to counter balance the biases embedded in the use of the fixed backward citation window. The use of the fixed backward citation window in traditional patent analyses does not reflect the various lengths of citation cycles in different domains, nor does it reflect the chronologically changing nature of citation cycles. Our dynamic CW based measure effectively solves the problems by using annual CW values in patent CR analyses. It offers a sound basis for assessing the real impact of patents. Further, the measure can be effectively used for comparing patent impact within and across technological domains. Normalized citation rates (nCR) can be derived by analyzing the overall backward citation rates of the entire parent domain and serve as the basis for comparing multiple individual domains under the parent domain. Patent data of three technology domains—the semiconductor, LCD, and drug industries—were analyzed to demonstrate the strengths of our approach over the traditional fixed CW based analyses. Through this analysis we have shown that each technology domain is dynamic in terms of its patent impact period, and the pace of technology progress varies from domain to domain. We have further demonstrated that trends of citation impact can vary greatly between industries due to domain differences. This in turn supports our construction of a dynamic backward citation widow for patent bibliometric analyses.

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