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An empirical research on the field of wireless charging based on patent life length①

Shi Min(施 敏)[*,**], Wang Juncheng②[***], Zhou Xiaodan[***], Hu Yiyuan[****], Zhao Zelong[****]
([*] School of Information Management, Wuhan University, Wuhan 430072, P. R. China)
([**] Institute of Scientific and Technical Information of Guangxi, Nanning 530022, P. R. China)
([***] Institute of Scientific and Technical Information of China, Beijing 100038, P. R. China)
([****] School of Information Resource Management, Renmin University of China, Beijing 100872, P. R. China)

Abstract

With the aid of patent life cycle theory, and from the perspective of patent life span, this paper choose the 'times of citation- time sequence' data of patents as an observation index to research on related patents in the field of wireless charging by applying the adjusted 'double-proportion' obsolescence method. The research reveals the rules of patent life span in the field of wireless charging, finding that the first 5 years since patents were authorized is the core period for the patents to play their full value, and also discovers the development law of merging technology patents.

Key words: life span of patent, patent information, 'double-proportion' obsolescence method

0 Introduction

With the rapid development of science and technology, intellectual property gains increasing attentions. Large amount of patent information with detailed content and standardized format produced in this process follows the law of information obsolescence like other scientific literature and network information. Meanwhile, multi-level qualification examination of patents guarantees the novelty, practicability and creativity of patent information while their timeliness insures that patent literature can present technological innovation at the soonest and objectively reflects the innovation trend of technology as well as the strength of technological innovation of related enterprises. The measure for the life span of patent information becomes a new perspective to grasp the trend of technological innovation and evaluate the competitiveness of technology-based enterprises.

Wireless charging is a relatively new and vibrating industry, however, its related patents with classic feature can be traced back long time ago. Hence, 'double-proportion' obsolescence method is adopted to measure the life span of patents in the field of wireless charging, and its law of development combined with examples is further explored with in-depth analysis.

1 Measurement of patent life span

1.1 Methods of the measurement of patent life span

The patent life span, studying patent life cycle from the time dimension, refers to the length of time lasting from the time when a patent being authorized to the time when the patent value declines to infinite low. In the research of the measurement of patent life span, the core issue is how to determine the obsolescence point of a patent. To sum up, there are mainly three methods to determine the obsolescence point in recent years:

Firstly, the life span of information can be determined by half-life of an information set and the Price index. Academics including Harter[1], Bugeja[2], and Koehler[3] taking websites or web pages as objects, refined 'link decay' as the measurement standard of information obsolescence and then calculated the half-life of the 'link obsolescence' in an information set, that is, the time during which half of links in the set has obsolesced. Due to the particularity of patent information, half-life of the sets and the Price index are inappropriate to the determination of individual obsolescence of information.

Secondly, the information can be deemed to be obsolesced when the utilization frequency reaches a

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② To whom correspondence should be addressed. E-mail: wangjc@istic.ac.cn
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certain proportion P. This method is an extension to the research method of individual half-life , and it is not feasible since every single information needs to be tracked until it is unattended.

Thirdly, the information without any users' attention within a consecutive period T can be considered obsolesced. Wang, et al.[4] defined the life cycle of network information as a time span from the generation of network information to the stage when no users used this information, using page views to depict the process. The research results indicate that around 77% of web pages achieve their maximum in terms of users' interests on the first day after their birth, and for the rest users, their interests' peak within one week. In addition, the active period of more than 80% of the web pages with timeliness has lasted no longer than two weeks. However, it is unrealistic to judge whether the information is completely unattended, as the determination of the T value has become a difficulty due to the lack of the support of scientific methods, and is mostly set by experience.

1.2 The introduction of 'double-proportion' obsolescence method of life span

As economic index is hard to get, academics mostly measure the value of patent by its citation[5]. Therefore, 'double-proportion' obsolescence adopted in this paper also employs the patents' citation as data basis to determine the obsolescence point of a patent[6]. The method combines thoughts of two methods, respectively cumulative citation percentage and continuous silent time, to determine the single patent obsolescence time with considering the proportion of obsolesced sample patents in the total sample patents. The method plays an important role when determining the obsolescence point of network information on the NetEase news, the Strong China Forum, and so on. It can also be used to determine the measure of obsolescence in other types of information[7] according to the difference of information life span by adjusting the P value.

The core ideas of 'double-proportion' obsolescence method are as follows. First, given a patent in the sample set, T is defined as the first consecutive period (T units) that the patent received no citation, $P1$ is defined as the proportion of the number of citations the patent accrued till the end of T to the total number of citations the patent received during the entire observation window, and $P2$ is defined as the proportion of the number of patents meeting $P1$ and T constraints to the total number of patents in the sample set. Then T is iterated from small to large values to find the minimal T value that meets the given double-proportion $P1$ and $P2$ values as the optimal T, which will be used to determine the expiration time of the sample patent set and the judging criteria of its life length. The core steps of 'double-proportion' obsolescence method are as follows[8]:

(1) Determine N pieces of patents, and let Ni represent the i^{th} piece of patent.

(2) Calculate the citation frequency N_{ij} of each patent in each period during the calculating time span, where $i(1 \leqslant i \leqslant N)$ represents the patent, j represents the time period, and j' represents the end of calculating time.

(3) Calculate the cumulative citation numbers of the i^{th} patent from the authorized time to each period of time j as $\sum_{i=1}^{j} N_{ij}$, the total citation numbers of the i^{th} patent in statistical period as $S_i = \sum_{i=1}^{j'} N_{ij}$, the percentage of the cumulative citation numbers of the i^{th} patent from the authorized time to each period of time j as $\sum_{j=1}^{j} N_{ij}/S_i$.

(4) Count the starting time of the first consecutive time (T units) without citations of the i^{th} patent as t_i. The percentage of cumulative citation numbers of the i^{th} patent before t_i is $Pi = \sum_{j=1}^{t_i} N_{ij}/S_i$. If $Pi \geqslant P1$, and t_i will be considered as the obsolescence point of the i^{th} patent.

(5) Count the proportion of the patents that meet condition $P1$ in the sample patents as P'. If P' first meets the condition $P' \geqslant P2$ when T takes a certain value, T will be considered as the determine criteria of the obsolescence point of this sample patent set. The life span of the i^{th} patent will be the temporal difference between t_i and its authorized time.

2 Measurement of patent life span in the field of wireless charging

2.1 Data set acquisition

Considering time delay exists in patents citation, and number of patents citation is relatively small in recently years, therefore, the end of 2015 is chosen as the searching time, specifically December 10, 2015. This paper retrieves 7272 patents related to wireless charging after searching the USPTO's Issued Patents, involving a total of 91936 cited patents, and the searching time was December 10, 2015. After removing patents missing partial field, zero-cited patents and patents consolidating 'one country and more yards', a research data set of 240 valid sample patents was chosen, including 30031 cited patents and 91936 citations.

2.2 Data set preprocessing

Based on the relationship between patents in terms of citation, starting from the patents authorization, citation time, the citation frequency within that month and total citing frequency of each patent is calculated by month. The specific calculation method is shown in Table 1, which lists the timing distribution of citation in the patent No. 5923544t (document 'Noncontact power transmitting apparatus') in detail. The patent number '5923544' is a patent granted to Japan's TDK Corporation in July 1999, therefore there was no citation before July 1999. It can be seen from the table that up to December 2015, the patent received a total of 84 citations. It was first cited in the 7 th month after obtaining authorization, then second citation occurred in the 11 th month, and it was cited again in the 14 th month. Afterwards, the patent received attention continuously. Up to January 2013, the cumulative number of citations was 42 and the cumulative citation proportion reached 50% for the first time. The longest consecutive continuous period of zero citation was 17 months. The span of the patent from the first citation to the statistical deadline was 165 months.

Table 1 Patent 5923544 citation sequence distribution statistics table

Citation time	Citation frequency	Cumulative citation frequency	Cumulative percent	Citation time	Citation frequency	Cumulative citation frequency	Cumulative percent
…197601	0	0	0.0000	201010	1	37	0.4405
…	0	0	0.0000	…	0	37	0.4405
200002	1	1	0.0119	201105	1	38	0.4524
…	0	1	0.0119	…	0	38	0.4524
200006	1	2	0.0238	201202	1	39	0.4643
…	0	2	0.0238	201203	1	40	0.4762
200009	1	3	0.0357	…	0	40	0.4762
…	0	3	0.0357	201207	1	41	0.4881
200012	1	4	0.0476	…	0	41	0.4881
200103	1	5	0.0595	201301	1	42	0.5000
…	0	5	0.0595	201302	0	42	0.5000
200107	1	6	0.0714	…	…	…	…
…	0	6	0.0714	201507	1	75	0.8929
200111	1	7	0.0833	201508	4	79	0.9405
…	0	7	0.0833	201509	2	81	0.9643
200208	1	8	0.0952	201510	2	83	0.9881
…	…	…	…	201511	1	84	1.0000

2.3 Patent citation delay *DE*

In the fields of library and information, many scholars have different understandings and applications on time delay. Scholars like Wang Yuandi pointed out that the 'citation delay' of a paper refers to the delay between its publication date of this paper and the publication date of the article citing this paper[9]. But Han Zhiwei pointed out that readers benefited from reading the papers, the time lapse from then till the project has papers being published and new papers being cited, can be referred to as 'citation delay'[10]. It can be seen that according to the different contents of the study, different scholars have various determinations of the time difference called 'citation delay', but all reflect the timeliness of the papers. In this paper, the patent citation delay is defined as: the time difference between the patent authorization and its first time being cited.

It is found that all sample patents have different lengths of citation delay. Among the sample patents studied in this paper, the patent with the longest time delay is '5717311' granted to Japan's Ulead Corporation in February 1998. This patent was first cited in November 2014 and the citation delay is 201 months; the patent with the shortest citation delay is patent '8588689' authorized to Microsoft Corporation in November 2013, and it was first cited in December 2013. The citation delay is only 1 month. It can be found that there is a great difference between citation delays among different patents. In order to reduce the influence of the citation delay on the patent life span, this paper calculates the mean *DE* of citation delay of sam-

ple patent and applies it to the judgment of 'double-proportion' obsolescence. Through the calculation, the average citation delay for sample patents is 27 months.

2.4 Calculation of patent *T* value

The criteria to determine patent *T* value is that a patent has not been cited in consecutive time (T units) in certain period starting from the patent's authorization to the end of the observation period (December 2015). With the introduction of 'citation delay', patents that require value *T* to be determined are divided into three categories. In the first category, if a patent has not been cited within the ($T + DE$) unit time after the authorization, it is considered to be obsolete with no length of life since its life has not yet begun. Such patents cannot be included in subsequent studies. In the second category, if a patent is cited within the ($T + DE$) unit time after the authorization, the time of first citation is the starting point, after that, if the patent has not been cited for consecutive time (T unit) during the observation period, it has an observable length of life. Therefore the time of obsolescence is defined as the starting point of consecutive time phrases of no citation in the first T unit time, and the length of life refers to the time period from the authorization date to this starting point. In the third category, if a patent is cited within the ($T + DE$) unit time after the authorization, and there is no case of 'no citation within consecutive T unit time' till the end of observation period, which means the patent has obsolescence time and length of life and has been frequently cited during the observation period. The actual time of obsolescence cannot be observed because patent's life has not yet ended till the end of the observation period (December 2015). Such patent is known as the right-censored patent.

To determine the proportional P, most of the scholars are in favor of 80-20 rule in their researches, and they believe that when a paper or a webpage has been browsed by 80 percent of users, even if there will be other users to browse continuously, the value of the information at that time has been greatly reduced. Compared with the paper or webpage information, the patent information has worse timeliness. Meanwhile, as an emerging technology, patents with serious right-censored phenomenon exist in the field of wireless charging technology , so in this paper, obsolescence proportion $P1$ and $P2$ are set as 60% , and this is set as a criterion to determine the validity of T.

This paper employs exhaustive method to determine the validity of T. Combined with the research and common sense of scholars, this paper sets the range of T from 1 to 50. Under the condition of double-proportion 60% −60% , the obsolescence of the sample patent was calculated when the value of T is taken as 1, 2... 50 respectively. Table 2 shows the distribution and obsolescence rates of selected patent categories under different T, the observation time is from January 1995 to December 2015, and the total number of sample patents is 4541. The first type of patents in the table refers to the patent that hasn't been cited for the first time in the period of ($T + DE$) months from the approval date; the second type of patents refer to the number of obsolescence patents during the observation time; the third type of patents refers to the number of patents that are not expired during the observation time;

Table 2 T value determination statistics excerpt

T	The first type of patent		The second type of patent		The third type of patent		Valid-$P1$ patent number	Valid-$P2$ proportion
	Number	Proportion	Number	Proportion	Number	Proportion		
1	1574	0.347	2924	0.644	43	0.009	507	0.185
2	1500	0.330	2931	0.645	110	0.024	553	0.218
…	…	…	…	…	…	…	…	…
12	896	0.197	2361	0.520	1284	0.283	596	0.516
13	851	0.187	2308	0.508	1382	0.304	608	0.539
14	808	0.178	2234	0.492	1499	0.330	607	0.564
15	766	0.169	2159	0.475	1616	0.356	613	0.590
16	730	0.161	2081	0.458	1730	0.381	605	0.613
17	699	0.154	1991	0.438	1851	0.408	596	0.637
18	664	0.146	1925	0.424	1952	0.430	582	0.654
19	637	0.140	1863	0.410	2041	0.449	575	0.670
20	611	0.135	1802	0.397	2128	0.469	575	0.688
…	…	…	…	…	…	…	…	…

the number of obsolescence $P1$ patent refers to the number of invalid patent citation within the effective life span occupying more than $P1$ (60%) of the total citation number during observation time; the obsolescence-$P2$ proportion refers to the proportion of the number of invalid-$P1$ patents and the number of non-obsolescence patents in the total number of invalid patents and non-obsolescence patents.

From the statistical results, it can be seen that when T is 16, the proportion of patents with citation frequency of transfer obsolescence greater than $P1$ is 61.3%, exceeding $P2$ (60%) for the first time, at the same time, it can be found that when T is equal to 16, the total citation frequency of obsolescence patent and the number of obsolescence-$P1$ patent begins to show a downward trend. Thus, under the criterion of double-proportion 60% – 60%, when T is equal to 16, the judgment condition is satisfied and the total cited frequency of obsolescence patent reaches the maximum under the condition of double-proportion, so effective T is 16.

2.5 Analysis of patent life span

Before 1995, wireless charging related technologies were at an embryonic stage, lacking the basis for snowball marketing due to its low user attention. In this stage, 6475 patents authorized from 1995 to 2015 are analyzed, of which altogether 4541 patents are cited during the observation time period. The life span of 4541 sample patents are measured based on the standard that effective T value is 16. Among them, 730 sample patents had not been cited for 43 consecutive months ($DE + T$) since authorization, 2081 patents had a specific obsolescence point during observation time, and 1730 patents had not obsolesced during observation time, that is, the right-censored patents. Table 3 lists the life span of 2081 obsolesced patents during observing time.

Table 3 Life span distribution of sample patents

Patent life span(month)	Patent quantity	Patent quantity proportion	Patent life span(month)	Patent quantity	Patent quantity proportion
[0 – 36)	1292	62.09%	[100 – 120)	20	0.96%
[36 – 60)	556	26.72%	[120 – 200)	29	1.39%
[60 – 100)	184	8.84%	/	/	/

The shortest patent life span of obsolesced patents is 4 months, and the longest one is 196 months. Over 80% of the patents have a life span of 60 months (5 years). Only 1.39% of patents have a life span over 10 years, and these patents have strong vitality as well as great influence on the development of wireless charging technology. It can be found that 98.61% of patents complete their patent value within 120 months (10 years), and lose their dissemination and utilization value. In general, patent life span in the field of wireless charging is overall shorter, the obsolescence rate is faster, and related technology is still in a rapid development stage (Fig. 1).

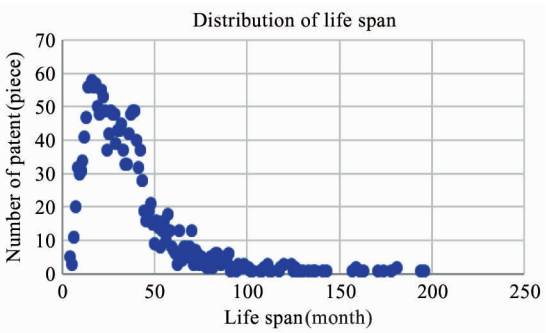

Fig. 1 Life span distribution of sample patents

According to the table of patent life span and survival analysis function, further analysis on the survival of the sample patents is conducted. As shown in Table 4, one month is set as unit interval span, patent life span is divided into 247 time segments, the monthly life span distribution of sample patents is counted respectively and finally the relevant life function images can be drawn. The life function images include curves of the cumulative survival function, the density function and the hazard function, respectively.

The curve of cumulative survival rate reflects the proportion of the number of patents that is still active in the total number of samples per time unit. It can be seen that patents in the field of wireless charging decline significantly in the first 6 years (Fig. 2). The patents in this field have a generally low survival rate, and life span is mostly within 6 years; the probability density function reflects the distribution rule of the sample patents in each life span interval, namely the proportion of the patents with same life span. As indicated in Fig. 3, the probability density concentrates in the first 6 years life span intervals, illustrating that the first 6 years after the authorization is the core time for patents to play their value. Two patent obsolescence peaks lie in the third year and the fifth year after

Table 4 Life table of patent information (excerpt)

Interval time	Enter quantity (ei)	Limited quantity (li)	Obsolescence quantity (di)	Adventure quantity (ni)	Conditional obsolescence rate (qi)	Conditional survival rate (pi)	Cumulative survival rate(si)	Probability density (fi)	Hazard rate(hi)
1	3811	0	0	3811	0.00%	100%	100%	0.00%	0.00%
2	3811	0	0	3811	0.00%	100%	100%	0.00%	0.00%
3	3811	0	0	3811	0.00%	100%	100%	0.00%	0.00%
4	3811	0	0	3811	0.00%	100%	100%	0.00%	0.00%
5	3811	0	5	3811	0.13%	99.87%	100%	0.00%	0.13%
…	…	…	…	…	…	…	…	…	…
21	2974	31	48	2958.5	1.62%	98.38%	84.06%	1.40%	1.64%
22	2895	16	55	2887	1.91%	98.09%	82.69%	1.36%	1.92%
23	2824	20	53	2814	1.88%	98.12%	81.12%	1.58%	1.90%
24	2751	31	49	2735.5	1.79%	98.21%	79.59%	1.53%	1.81%
25	2671	29	37	2656.5	1.39%	98.61%	78.16%	1.43%	1.40%
…	…	…	…	…	…	…	…	…	…
245	6	1	0	5.5	0.00%	100.00%	16.80%	0.00%	0.00%
246	5	2	0	4	0.00%	100.00%	16.80%	0.00%	0.00%
247	3	0	0	3	0.00%	100.00%	16.80%	0.00%	0.00%

authorization and patents in this field that last until 8 years later are of less number; the hazard function reflects the probability of patent obsolescence in each life span interval. As shown in Fig. 4, the curve has several rises and falls. In the 4 time segments of the early period, the probability of patent obsolescence is larger and it indicates a trend of rapid growth. After that the curve rapidly drops and the obsolescence probability declines to a low level showing a gentle trend of change. From here we see that the patent faces relatively high obsolescence risk in the first 5 years after authorization, and then the patent hazard rate begins to decline and in the eighth and eleventh year reaches a small peak of obsolescence. The obsolescence probability of the sample patent that has gone through the obsolescence peak becomes smaller and it is cited continuously by other patents later on, and finally becomes the core technology patent in the field.

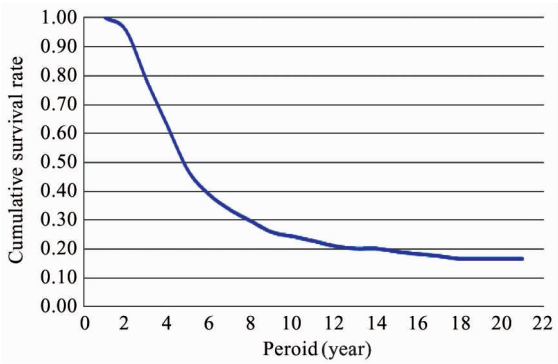

Fig. 2 The distribution map of cumulative survival rate

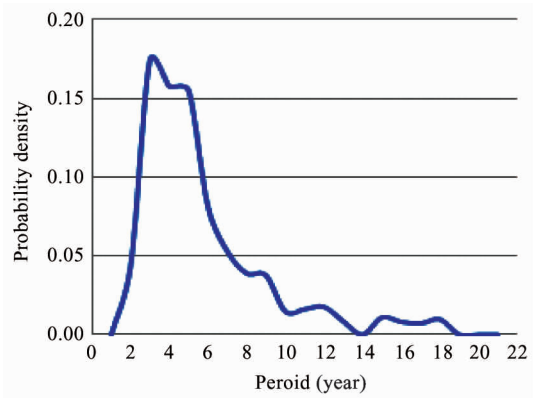

Fig. 3 The distribution map of probability density

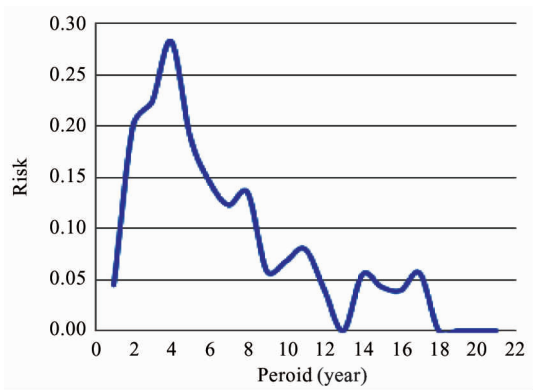

Fig. 4 The distribution map of hazard rate

3 Conclusion

The changes of patent information life span present the development stage of the related technical field

to a certain extent[11]. At the same time, the span also presents the value of a patent. Through the analysis of the field of wireless charging from the perspective of patent life span, five conclusions can be drawn as follows:

From the perspective of the analysis method, the paper improves 'double-proportion' obsolescence method according to the particularity of patent information, and reduces the double-proportional P value to conform to the characteristics of patent information. However, as an emerging technology[12], wireless charging is at the peak of patent application in recent years. The time scale selected in this paper ended by the end of the observation, hence the data in recent years cannot be acquired completely, and a certain number of 'right-censored' data has not been included, which may result in system errors.

From the perspective of the analysis results, an average citation delay of patents in the field of wireless charging is 27 months. On one hand, because wireless charging has just got rapid development in recent two years, the early patents in the retrieval results have weak connection with wireless charging, and the phenomenon of innovation based on the early patents is common. On the other hand, recent patents were partially counted due to the time limits for data acquisition, leading to a slightly larger citation delay.

From the perspective of the patent T value, patents in the field of wireless charging are obsolesced if they are not cited for consecutive 16 months. This emphasizes the timeliness of patents in this field compared with other industries, and also shows that the field is still in the rapid developing stage with a rapid update and iteration speed of the patents[13]. A large number of low-value patents have been quickly eliminated.

From the perspective of the average patent life span, 60% of the patents reach the obsolescence point within a year and a half while nearly 90% of the patents will reach the end of life within 5 years. Fewer patents have long-term influence on the development of wireless charging technology. It generally shows a feature that the life span is short while the eliminating speed is fast.

From the curve of patent survival analysis, it can be seen that the first 1 – 5 years is the peak period of patent obsolescence, in which the obsolescence patent quantity has the widest distribution and the obsolescence risk is at the greatest level. In the early stage of development, a large number of patentees applied for massive patents to preempt the market, resulting in the lack of core technology in patents and inability to keep a long-term development. Referring to the conclusions above, the future inventors should consider the characteristics of patents in the field of wireless charging, abstract the technological key points from a large number of new authorized patents, pay attention to information integration and increase investment, thereby contributing more to patents with strong vitality.

This study adopts the 'double-proportion' obsolescence method to analyze the patent life span in the field of wireless charging. Because wireless charging is a newly developing field with a short developing time, the retrieval, acquisition and statistics of patent information is still incomplete. The field with mature technology will be selected for further research. In addition, the selection ranges of samples still need further extension. The USPTO data selected in this paper limits the national scope of patent applications in the field of wireless charging, and the imperfection of samples may also bring deviation to the measure of life span; at the same time, due to the limited space, the core enterprises in the field of wireless charging have not been included for technology competitiveness evaluation. Thus, the evaluation of the competitiveness and development prospects of related companies can be evaluated in future researches by investigating the life span of patents they apply.

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Shi Min, born in 1974. She is a Ph. D candidate of Information Management School at Wuhan University. Meanwhile, she is an associate researcher serving in Institute of Scientific and Technical Information of Guangxi . She was a visiting scholar of Oxford University from November 2015 to November 2016. Her current research interests focus on technology transfer services research, Intellectual property research, scientific and technical finance research.